Commonwealth Agricultural Bureaux

Commonwealth Institute of Entomology

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Report of the Fifth Commonwealth Entomological Conference

22nd-30th July

1948

LONDON
COMMONWEALTH INSTITUTE OF ENTOMOLOGY
41 QUEEN'S GATE S.W.7
DECEMBER, 1948

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FOREWORD

By Lieutenant-Colonel J. G. Robertson, B.S.A., F.R.S.A.,
Chairman of the Executive Council of the Commonwealth Agricultural Bureaux

It has been the aim for many years past to hold a Conference of the entomologists of the Empire at five-yearly intervals. Owing to the intervention of the war period, however, thirteen years have elapsed since the last Conference was held in 1935. During this period the study of entomology, not only in the field of agriculture but also in those of medical and veterinary science, has assumed greater importance than ever before and considerable advances in the knowledge of the subject have been made. It was, therefore, particularly desirable that the fifth in this series of Conferences, which have been of such value to entomologists in the past, should be held. Another function of these gatherings is to provide an opportunity for detailed consideration of the work carried out on behalf of the contributing Governments by the Commonwealth Institute of Entomology. Many changes have taken place since the last Conference was held so it was all the more important that the scientific and technical activities of the Institute should be reviewed and that personal contacts between the staff and overseas entomologists should be renewed.

The Conference lasted ten days and the high attendance at all the scientific meetings was an indication of the great interest aroused. Three Committees were formed which dealt with the matters put before them in the most thorough manner. Many resolutions were adopted by the Conference, including the recommendations forwarded by the various Committees, and these will receive the early and careful consideration of the Executive Council.

J. G. Robertson,
Chairman of the Executive Council,
Commonwealth Agricultural Bureaux.

REPORT

OF THE

Fifth Commonwealth Entomological Conference

22nd–30th July, 1948

Calling of the Conference

The Fourth Imperial Entomological Conference, at its final meeting on 27th September, 1935, passed the following resolution:—

> "The Conference endorses the opinion expressed at previous Imperial Entomological Conferences as to the value of periodical meetings of entomologists and recommends that steps be taken in due course for a Fifth Imperial Entomological Conference to be held in London in 1940, of which at least four months' notice should be given."

There was an unavoidable delay in acting in accordance with this resolution on account of the War, but invitations were conveyed to the Governments of the British Commonwealth for a Conference to be held in London from the 22nd to the 30th July, 1948. This date was selected so that delegates could attend in addition the 8th International Entomological Congress that was due to be held in Stockholm from the 9th to the 14th August.

List of Delegates and Observers

The following official delegates attended.

Australia.

Dr A J Nicholson
Mr. R. T. M Pescott.
Mr. F N Ratcliffe.

Canada.

Mr A. B Baird
Mr. H. G. Crawford.
Mr W. A Ross.

Colonies, Protectorates and Mandated Territories.

Mr. J. P Bernacca (Uganda)
Mr J. Bowden (Gold Coast)
Mr. G. F. Clay, C M G., O.B E , M C. (Colonial Office).
Mr J. T Davey (Nigeria)
Dr. W. F. Jepson, O.B E (Tanganyika).
Prof T. W. Kirkpatrick (Trinidad).
Dr. R H. Le Pelley (Kenya)
Dr. K. R. S Morris (Gold Coast)
Mr A Moutia (Mauritius).
Prof J. W. Munro (Colonial Office)
Dr T. A M Nash, O.B E (Nigeria).
Mr. J. Nicol (Gold Coast).
Mr. H. T Pagden (Malaya)
Dr. H. H. Storey, C.M.G., F R.S , (Colonial Office).
Mr C. B. Symes, O B E (Colonial Office).
Dr. B. P Uvarov, C.M.G (Colonial Office)

Eire.

Dr. J. Carroll.

India.

Dr. K. B. Lal.
Dr. H. S. Pruthi, O.B.E.

New Zealand.

Dr. W. Cottier.
Dr. D. Miller, F.R.S.N.Z.

Southern Rhodesia.

Mr. M. C. Mossop.

United Kingdom.

Dr. A. E. Cameron.
Mr. R. Chamberlain.
Dr. J. A. Freeman.
Dr. R. A. E. Galley.
Mr. C. T. Gimingham, O.B.E.
Mr. G. V. B. Herford, O.B E.
Mr. J. W. McHardy.
Dr. G. D. Morison.
Dr. E. E. Turtle, M.B.E.
Mr. A. R. Waterston.
Dr. V. B. Wigglesworth, F.R.S.
Dr. D. W. Williams.

In addition the following attended as observers:—

Anglo-Egyptian Sudan.

Mr. W. P. L. Cameron.
Mr. J. W. Cowland.

Australia.

Mr. G. L. Wilson.

Eire.

Prof. J. Bayley Butler, M.B E.

United Kingdom.

Dr. R. C. Fisher.
Mr H. S. Hanson.

Programme

The programme was as follows:—

Thursday, 22nd July

10.30 a.m. Reception of Delegates by Lieutenant-Colonel J. G. Robertson, B.S.A., F.R.S.A., Chairman of the Executive Council of the Commonwealth Agricultural Bureaux.
First Business Meeting.

4 p.m. Reception at the British Museum (Natural History), Cromwell Road, S.W.7.

Evening. Official Dinner to the Delegates given by His Majesty's Government at Claridges Hotel, Brook Street, W.1.

Friday, 23rd July

10 30 a m. *Chairman:* Sir John C. F. Fryer, K.B.E., F.R.S.

Discussions: "Recent Developments in Insecticides." Opener: Dr. R. A. E. Galley.

"Mode of Action of new Insecticides." Opener: Dr. V. B. Wigglesworth, F.R.S.

"Uses and Limitations of the new Insecticides in the Field." Opener: Mr. W. A. Ross.

*2.30 p.m. *Chairman:* Sir John C. F. Fryer, K.B.E., F.R.S.

Discussions: "Recent Developments in Pest and Disease Control Machinery." Openers: Dr H. G. H. Kearns, Dr. G. H. Berkeley.

"Application of Insecticides from the Air" Opener. Dr. D L. Gunn.

Evening Conversazione given by the Council of the Association of Applied Biologists at The Botany Department, Imperial College of Science and Technology, Prince Consort Road, S.W 7.

Saturday, 24th July

Visit to Rothamsted Experimental Station and Whipsnade.

Monday, 26th July

Morning. Reserved for Meetings of Committees.

2.30 p m. *Chairman:* Dr. A. J Nicholson.

Discussions: "Biological Control." Openers: Mr. A. B. Baird, Dr. W. Cottier, Dr. R. H. Le Pelley, Dr. D. Miller, F.R S N Z.

"Estimation of Insect Populations in the Field" Opener: Mr. A. H. Strickland.

Tuesday, 27th July

10.30 a m *Chairman:* Professor J. W. Munro.

Discussions: "Recent Developments in the Control of Stored Products Insects." Opener: Mr. F N Ratcliffe.

Chairman: Mr. C. B. Symes, O B E.
"Tsetse Research and Control" Opener: Dr T A M. Nash, O.B.E.

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Discussion: "The Need for Plant Quarantine on a Continental Basis, with special Reference to Africa" Opener: Mr G F Clay, C M G, O B E, M C

Wednesday, 28th July

Visits to the Field Station of the Imperial College of Science and Technology at Silwood Park, Sunninghill, near Ascot, and to the Stored Products Research Laboratory, Slough.

* Joint Meeting with the Commonwealth Mycological Conference.

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Dr. J. Carroll.

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Dr. H. S. Pruthi, O.B.E.

New Zealand.

Dr. W. Cottier.
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Mr. J. W. McHardy.
Dr. G. D. Morison.
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* Joint Meeting with the Commonwealth Mycological Conference.



Thursday, 29th July

Morning. Reserved *for Meetings of Committees.*

2.30 p.m. *Chairman:* Mr. H. G. Crawford.
*Discussion: "Locusts and Grasshoppers." Opener: Dr. B. P. Uvarov, C.M.G

8.30 p.m. Conversazione given by the Royal Entomological Society of London, *at 41, Queen's Gate, S.W.7.*

Friday, 30th July

Morning. Final Committee Meetings.

Afternoon. Final Business Meeting.

Place of Meetings

By the courtesy of the President and Council of the Royal Entomological Society of London, the plenary sessions of the Conference were held in the Meeting Room of the Society at 41, Queen's Gate, S.W.7, and by the courtesy of the Imperial College of Science and Technology, the "discussions" in open meetings were held in the large Chemical Lecture Theatre of the Royal College of Science, Imperial Institute Road, S.W.7.

Opening of the Conference

The Conference assembled on the 22nd July. The chair was taken by Colonel J. G. Robertson, B.S.A., F.R.S.A., who welcomed the delegates in the following speech†:—

I wish first of all to welcome the delegates to this, the Fifth Commonwealth Entomological Conference. It is a pleasure to see such a good attendance; at the last Conference there were only 27 official delegates, whereas there are double *that number here today*

At the Imperial Agricultural Bureaux Review Conference in 1946, I had the pleasure of introducing the Earl of Huntingdon, Parliamentary Under Secretary to the Minister of Agriculture, to open the Conference officially, but the official opening of this Conference has been left to a Canadian, and my only claim to the honour is that I am Chairman of the Executive Council of the Commonwealth Agricultural Bureaux, which extended the invitation to the Governments of the Commonwealth to hold this Conference.

As Chairman of the Executive Council, I might pause a moment to explain to you what that body is and of whom it consists. To quote the Imperial Agricultural Bureaux Conference Report of 1946: "The Executive Council of the Imperial Agricultural Bureaux is an intra-imperial organization organized on the basis of the principles laid down by the Imperial Conference of 1926". It consists of one representative of Great Britain and each of the Dominions, including Southern Rhodesia, and one member representing the Colonies. Until 1946 Sir David Chadwick was Secretary and since then Sir Herbert Howard, both very capable and efficient.

The Executive Council directs two Institutes and ten Bureaux, besides the Bureau of Biological Control and the Commonwealth South American Potato Collection. There are, therefore, 14 bodies under its jurisdiction.

This Conference has to do with the Commonwealth Institute of Entomology and I hope that it will prove a very successful gathering; I am sure that it will.

* This discussion was preceded by an account of the history of the Bureau of Biological Control by Sir Herbert Howard and followed by a short discussion on Termites under the chairmanship of Mr. F. N. Ratcliffe.

† Somewhat abridged.

Here let me explain the fact that sometimes we refer to "Imperial" and sometimes to "Commonwealth" Institutes or Bureaux. They were "Imperial" until nine months ago when, at the request of certain Dominions, it was decided by the Executive Council to change the name from "Imperial" to "Commonwealth", and such it has been since 1st January, 1948. The name matters little; it is the activities that count.

The Imperial (to give it its first name) Institute of Entomology was founded in 1913. It was then called a Bureau and is the senior of the Imperial (or Commonwealth) Agricultural Institutes or Bureaux. The first director was Sir Guy Marshall, who was the head of the Bureau or Institute from 1913 until he retired in 1942—a period of 29 years. Upon Sir Guy's retirement Dr. Sheffield Neave, who had been Assistant Director for 28 years, became Director. He in turn retired in 1946 It is impossible to over-estimate the value of the services of these two very eminent entomologists in creating and building up the Institute. The reputation won by the Institute, not only within the Commonwealth but internationally, was very largely due to their efforts It is particularly gratifying to know that both of them are well and active in their retirement and maintain their interest in entomology.

The present Director, Dr W. J. Hall, was appointed Assistant Director in 1944 and became Director on Dr. Neave's retirement in 1946. I trust that Dr. Hall will be equally successful as a distinguished director and when, many years from now, he comes to retire he may, like his eminent predecessors, be able to enjoy many more happy years.

The last Entomological Conference was held in 1935, one year later than the Mycological Conference. It was intended to hold them at five-yearly intervals, but in 1940 we were in the midst of a very serious and tragic war, so a Conference was out of the question. The war lasted until 1945, but, in fact, it is difficult to say whether peace has yet been established throughout the world. The last Imperial (now Commonwealth) Agricultural Bureaux Review Conference was held in 1946. Among many other things considered was the usefulness of and need for specialist Conferences, and the early resumption of Entomological and Mycological Conferences was recommended to the Executive Council In April 1947, the Executive Council decided to invite Governments to hold an Entomological Conference in London in 1948. Here we have the Conference in July 1948.

Conferences from time to time are excellent They present an opportunity for men (and women too) to get together, exchange ideas, consider problems, discuss matters of mutual concern and plan for the future. A Conference such as this should certainly be of great value for dealing with scientific subjects and technical matters, but probably the greatest good will be the personal contacts made and the exchange of ideas outside the Conference proper.

Twice in its history have the activities of this Institute been affected by war. Fortunately during the recent conflict no material damage was done, but the staff carried on under very difficult conditions In fact, conditions are still difficult, although one now has confidence that one's home will be intact when one returns to it at night which was not the case in war-time. However, in war and in peace, the *Review of Applied Entomology*, both series, has appeared regularly monthly, the *Bulletin of Entomological Research* has been issued quarterly and other services have been rendered as usual

Two of the activities initiated and developed by the Institute have assumed a separate existence since the last Conference. The Parasite Laboratory at Farnham House, established in 1927, was transferred to Canada in 1940 owing to the difficulty of carrying on its operation in Great Britain and on the Continent under

wartime conditions. The Imperial Agricultural Bureaux Conference of 1946 recommended that it should be made into a separate Bureau and the Imperial (now Commonwealth) Bureau of Biological Control came into existence on 1st April, 1947, under Dr. Thompson.

In 1939, locust investigations came under the control of the Inter-departmental Committee on Locust Control at the Colonial Office, and in 1946 became a separate entity as the Anti-Locust Research Centre. The international contacts and co-operation necessary to the efficient development of the work of controlling locusts was very largely instrumental in this decision.

Possibly some of you may remember that at the 1935 Conference a resolution was passed requesting the Institute to collect information on termites from the various parts of the Commonwealth. A questionnaire was sent out in due course, and the information contained in the replies has been summarised in a paper that has been circulated to all delegates. You will have an opportunity of discussing this summary and deciding what action, if any, should be taken upon it. It may be that you will wish to form a small committee to consider it and report at the meeting when it is to be discussed.

A very full programme of meetings, broken by two separate days of outings, has been arranged for you The items on the agenda for the open meetings have been chosen with a view to their importance and wide interest. You will notice, for instance, that prominence has been given to the question of insecticides in view of the great advances that have been made in recent years in this field. I am confident that your discussions on this and the other subjects, and the interchange of information that will result, will prove of great interest and value.

The financial provision for the Institute for the period 1st April, 1947, to 1st April, 1952, was agreed at a meeting of the Imperial Agricultural Bureaux Conference in 1946 and was subsequently accepted by Governments. This will be reviewed again at the next Bureaux Conference, which is due to be held in 1950, so you will realise that the Institute is working on a fixed budget determined by the sum total of the contributions of Governments. Certain matters arising from the last Review Conference have been referred to this Conference for discussion and you will no doubt wish to discuss others relating to the activities of the Institute. This will be very welcome, as the Council is anxious to have your recommendations. Details of the activities of the Institute will be given by Dr. Hall in his report. Much has been accomplished and much remains to be done

The world food situation is so precarious and foods are in such great demand in many parts of the world that there is vital need for developing our information service in entomology to the utmost in view of its great importance to agriculture.

The Executive Council will await with great interest the report of this Conference together with any recommendations you may see fit to put forward, and you may rest assured they will receive the most serious consideration.

It is, therefore, with great confidence in you, Gentlemen, and with high hopes that your deliberations will be valuable and with a very cordial welcome to all delegates and visitors that I now declare the Conference open.

Activities of the Institute

The opening of the Conference was followed by a business meeting at which the Director discussed the Memorandum (Appendix I) on the work of the Institute for the past 13 years, which had already been circulated to all delegates. There had also been issued to delegates a summary of information on termites and certain papers in connection with the discussions that were to take place on continental quarantine.

After a short discussion, a special business committee was appointed to give detailed consideration to the activities of the Institute, and any other matters that delegates might wish to raise.

The Committee was composed as follows:—

Prof. J. W. Munro (Chairman) ...	Colonial Office Delegation.
Dr. J. Carroll	Eire.
Mr. H. G. Crawford	Canada.
Mr. C. T. Gimingham, O.B.E. ..	United Kingdom.
Dr. W. F. Jepson, O B E. .	Tanganyika.
Dr. R. H. Le Pelley . . .	Kenya.
Dr. D. Miller	New Zealand.
Mr. M. C. Mossop .	Southern Rhodesia.
Dr. A. J. Nicholson .	Australia.
Mr. W. V. D. Pieris	Ceylon.
Dr. H. S. Pruthi, O.B.E.	India.

Sir Herbert Howard, Secretary of the Commonwealth Agricultural Bureaux, and Dr. W. J. Hall, Dr. T. H. C Taylor and Captain H S Bushell, all of the Commonwealth Institute of Entomology, attended all meetings of the Committee but were not members of it.

A report of the work of this Committee is given in Appendix IIa It submitted its recommendations at the final meeting of the Conference when they were amended and then adopted and included among the resolutions passed.

A Termite Committee was also appointed to consider a summary that had been prepared and circulated of the information contained in the answers to the questionnaire sent in by the various countries of the Empire arising out of the recommendation of the previous Conference held in 1935 A memorandum on this summary, prepared by one of the delegates, had also been circulated.

The Committee was composed as follows:—

Prof J. W Munro (Colonial Office) (Chairman), Dr W Cottier (New Zealand), Dr. R. C Fisher (United Kingdom), Dr. W F Jepson, O B E. (Tanganyika), Prof T W Kirkpatrick (Trinidad), Mr M C Mossop (Southern Rhodesia), Dr H. S Pruthi, O B E. (India), Mr F N Ratcliffe (Australia).

The recommendations of this Committee were discussed in open meeting on the afternoon of Thursday, 29th July, and at the final meeting on the following day they were amended and then adopted as resolutions by the Conference

Papers and Discussions

The papers read at the scientific meetings of the Conference, together with a summary of the discussions that followed, are printed as Appendix III to this report

Official Dinner

His Majesty's Government gave a dinner at Claridges Hotel on the 22nd July in honour of the delegates to the Commonwealth Entomological and Mycological Conferences The Right Honourable the Minister of Agriculture, Mr. Tom Williams, M.P., presided and proposed the toast of "The Entomological and Mycological Conferences" The Chairman of the Executive Council, Col J. G. Robertson, replied on behalf of the Commonwealth Agricultural Bureaux. The toast of "The Delegates from Overseas" was proposed by Mr. P C Gordon Walker, M.P, Parliamentary Under Secretary of State for Commonwealth Relations, and responded to by Mr H G Crawford on behalf of the delegates to the Entomological Conference and by Dr J C Hopkins on behalf of those to the Mycological Conference

Visits, etc.

Visits were made to Rothamsted Experimental Station, Whipsnade Zoo, the Field Station of the Imperial College of Science and Technology at Silwood Park, Sunninghill, near Ascot, and to the Stored Products Research Laboratory at Slough. The delegates were also invited to a reception at the British Museum (Natural History), to a Conversazione given by the Council of the Association of Applied Biologists at the Botany Department, Imperial College of Science and Technology, Prince Consort Road, S.W.7, and to a Conversazione given by the Council of the Royal Entomological Society of London at 41, Queen's Gate, S.W.7.

Proceedings at the Final Meeting

At the final meeting of the Conference, the chair was taken by Col. J. G. Robertson, Chairman of the Executive Council of the Commonwealth Agricultural Bureaux.

After the resolutions recorded below had been adopted, a vote of thanks was passed, on the motion of Dr. D. Miller, on behalf of the delegates to the members of the Executive Council of the Commonwealth Agricultural Bureaux and to the officers of the Commonwealth Institute of Entomology for the successful manner in which the Conference had been conducted.

The Director thanked Dr. Miller on behalf of the staff of the Institute for his kind remarks and the Chairman, in bringing the Conference to a conclusion, also thanked Dr. Miller and expressed his personal satisfaction with the course the Conference had taken.

Conclusions and Resolutions

1. The Conference records its appreciation of the services rendered by the Commonwealth Institute of Entomology to scientific workers in the British Commonwealth, and of the outstanding work in the past of its former Directors, Sir Guy Marshall, K.C.M.G., and Dr. S. A. Neave, C.M.G., O.B.E. It notes with satisfaction that at the Imperial Agricultural Bureaux Review Conference held in July, 1946, financial provision was made to enable the services to be maintained for a further period of five years.

2. The Conference appreciates the careful consideration given by the Business Committee to questions submitted to it and makes the following resolutions (3-14) based on the recommendations put forward by that Committee.

Services of the Commonwealth Institute of Entomology

3. Research on economic entomology is increasing so rapidly that it is becoming impossible for the results of such work to be published within any reasonable time. Information of considerable value to other workers is thus being unduly withheld from those who would most benefit from it. Increased facilities for publication should, therefore, be made available through the medium of the *Bulletin of Entomological Research* by the adoption of the following *measures*:—

(*a*) The *Bulletin*, while still to be issued quarterly, should be increased in size, and the price increased appropriately to ensure that it remains self-supporting.

(*b*) Papers of purely local interest should be excluded, at the discretion of the Editor.

(*c*) Papers other than those of direct economic entomological interest should be excluded, at the discretion of the Editor.

(*d*) Authors should be requested to make their papers as short as is reasonably possible.

4. Papers dealing with the morphology and physiology of insects are already adequately covered in the *Review of Applied Entomology* or the *Insecta* Section of the *Zoological Record* and no variation of the present practice is necessary.

5. The *Review of Applied Entomology* is already giving adequate attention to insecticides and contrives to deal with the chemical aspect of insecticides in the manner required by entomologists. No variation of the present practice is necessary or desirable.

6. The subdivision of the *Review of Applied Entomology* into sections containing abstracts of papers dealing solely or mainly with specialised branches of entomology, such as insecticides or biological control, is impracticable.

7. It is impracticable for the *Review of Applied Entomology* to give a complete cover of information on the design and relative merits of different types of machinery and equipment for applying insecticides, and fuller information on these subjects is available from the Inter-departmental Insecticides Committee. The procedure at present adopted in dealing with these subjects in the *Review* should not be changed.

8. The identification service of the Commonwealth Institute of Entomology is of the utmost importance to entomologists in overseas countries of the Commonwealth and should be maintained. Furthermore, its extension should be considered at the next Commonwealth Agricultural Bureaux Review Conference.

9. The policy adopted by the Institute in regard to the acceptance or refusal of material submitted to it for identification by both Commonwealth and foreign countries, and also in regard to the order of priority that is given to such material according to its economic importance and source, is approved.

10. The Institute should encourage the revision of groups of insects involved in economic problems, and, within the limitations of its staff, undertake such revisions. In this connection the Conference draws attention to paragraph 45 on page 25 of the Report of the Imperial Agricultural Bureaux Conference, 1946, in which it was recommended that the Institute should stimulate taxonomic work amongst entomologists in the contributing countries.

11. The production of maps showing the distribution of insect pests is desirable, though of less importance than the extension of the identification service, but additional staff would be required to prepare them.

12. Periodic brief statements on the nature of research work in progress in all Commonwealth countries and on its application, and also on changes in the organisation of research, should be sent to the Institute so that such information may be made available to the greatest extent possible to other workers in the Commonwealth.

13. The Institute is faced with an acute shortage of accommodation. The Conference learns with satisfaction that the Executive Council has this problem in mind and earnestly trusts that a suitable solution to it may be found at an early date so that the activities of the Institute may not be impaired.

Biological Control

14. In view of the great interest in biological control and the importance, in general, of parasites and predators, the Conference resolves that a Committee consisting of delegates should be set up to consider various aspects of the organisation of biological control work in the British Commonwealth and that the Committee's conclusions should be submitted to the next Commonwealth Agricultural Bureaux Review Conference to be held in London in 1950.

Termites

15. The Conference adopts the recommendations of its Termite Committee and accordingly makes the following resolutions (16 and 17).

16. There is an urgent need for the expansion of research work on termites, particularly in the Colonies. One or more entomologists should therefore be appointed to study termites in the field, with particular reference to their biology and their relationship to agriculture and forestry, and to study their taxonomy at an appropriate Museum.

17. A simple manual, designed for the practical builder and dealing with the protection of buildings and building materials from termites, should be prepared, and the Building Research Station and the Forest Products Research Laboratory, both of the Department of Scientific and Industrial Research, *should be asked to* undertake its preparation in co-operation with appropriate authorities. The manual should be published by the Commonwealth Institute of Entomology.

The Nomenclature of Insecticidal Chemicals

18. The Conference adopts the recommendations of the Committee on the Nomenclature of Insecticidal Chemicals (see p. 26) and accordingly makes the following resolutions (19-23).

19. Common names for insecticidal chemicals should be universally agreed upon.

20. To assist in the achievement of this objective, the Commonwealth countries should form a Standing Committee to select and finally agree appropriate names.

21. This Standing Committee should comprise:

Chairman—The Director of the Commonwealth Institute of Entomology.

Secretary—The Secretary of the Inter-departmental Insecticides Committee.

Three representatives from the United Kingdom.

One representative from the Colonies collectively and one from each of the Dominions.

Members of the Committee resident in the United Kingdom should serve as a Central Working Committee.

22. This Standing Committee should work in closest collaboration with the appropriate U.S. authority.

23. The Conference hopes that similar action will be taken in connection with the nomenclature of fungicides, herbicides, rodenticides and other pest and disease control substances.

Continental Quarantine

24. The Conference adopts the following opinions and recommendations (25-28) concerning quarantine on a continental basis made by it in open session, and recommends that they be transmitted to the Phytosanitary Conference due to begin in London on the 2nd August, 1948.

25. This Conference supports the proposal for an African Phytosanitary Convention.

26. The Conference suggests that:

(i) such a Convention should initially embrace all the Territories south of the Sahara, including the Anglo-Egyptian Sudan, Ethiopia and Eritrea, and that these Territories should be regarded as one area for administrative purposes in connection with the introduction and quarantine of plants; the pest and disease position in the part of Africa north of the Sahara should be kept under constant review in order that, if considered necessary, steps could be initiated to secure the co-operation of countries concerned so as to extend the area covered by the Convention to embrace the whole of the Continent. Special consideration, however, will have to be given to certain difficulties of applying this Convention to the Anglo-Egyptian Sudan.

(ii) notwithstanding the previous suggestion, it might be necessary, for ease of administration, to organise regions within the area covered by the Convention. In this connection the Conference draws attention to the satisfactory arrangements now in operation in the southern African region, comprising the Belgian Congo, the Union of South Africa, Southern Rhodesia, Northern Rhodesia and Nyasaland, and in East Africa, comprising Kenya, Uganda, Tanganyika and Zanzibar, and further suggests that similar regional arrangements might be organised for other parts of the area.

(iii) while the legislation throughout the area should be uniform, it should also be as simple and concise as possible and any Territory should be free to make more stringent regulations if it is thought desirable to do so. In order to stimulate mutual confidence, consultation with other member states should be established as a principle.



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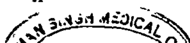
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(iii) while the legislation throughout the area should be uniform, it should also be as simple and concise as possible and any Territory should be free to make more stringent regulations if it is thought desirable to do so. In order to stimulate mutual confidence, consultation with other member states should be established as a principle.



(iv) a permanent commission, comprising representatives of the powers subscribing to the Convention, should be set up in Europe, charged with examining the existing arrangements in all Territories for the control of importation of plants, with a view to the institution and co-ordination of measures of protection against the importation of diseases and pests, as well as of measures against diseases and pests occurring in the several Territories.

(v) the possibility should be explored of, firstly, preparing a list of major plant pests, the introduction of which might constitute a serious menace to the African Continent, and, secondly, specifying in legislation those plant products that can be allowed free entry and those that are to be partially restricted, while all other importations are by permit only.

(vi) the establishment of quarantine measures is important and the commission should examine existing conditions and where necessary set up, or make recommendations for the setting up, of further quarantine stations.

27. Subject to the provision of adequate funds and staff, the Conference supports the recommendation of the Brussels Conference that the Commonwealth Institute of Entomology should be recognised as the centre of information on the distribution of plant pests.

28. The Conference considers that the danger of introducing diseases and pests by aircraft is very great and that there is an urgent need for uniform regulations designed to minimise it.

The Control of Pests of Stored Products

29. The Conference, from its discussions, learns with satisfaction of the progress made in Stored Products Entomology in many parts of the Commonwealth, and recommends that existing knowledge should be more fully utilised by Governments.

The Need for more trained Entomologists

30. The increase in production and storage of food necessitates an increase in research on existing entomological problems and on new ones that are constantly arising and also in the practical application of the results of such research. The supply of trained entomologists is at present quite inadequate even to fill existing vacancies in staff. The Conference therefore urges that Commonwealth Governments should encourage, by all means in their power, the training of entomological students, and should be prepared to make financial provision for the initiation and maintenance of essential research and practical control measures.

Acknowledgements

31. The Conference wishes to tender its grateful thanks to His Majesty's Government in the United Kingdom, the Trustees of the British Museum, the Association of Applied Biologists and the Royal Entomological Society of London for the hospitality extended to it, and to the last named also for the privilege of using its Council and Meeting Rooms. It also wishes to thank the Imperial College of Science and Technology for the use of one of its large lecture theatres for the open meetings.

32. The Conference wishes that its grateful thanks be conveyed to Dr. W. G. Ogg, Director of the Rothamsted Experimental Station, the President and Council of the Zoological Society of London, Professor J. W. Munro and Mr. G. V. B. Herford, O.B.E., and their staffs, for the welcome accorded to the delegates on their visits to Rothamsted, Whipsnade, Silwood Park and Slough, respectively, and for the interesting and instructive explanations of the work in progress at these centres.

Future Commonwealth Entomological Conferences

33. The reviews of work that have been submitted to the Conference by contributing countries are of great value, and such reviews, in as brief a form as is reasonable, should be a permanent feature of future Commonwealth Entomological Conferences.

34. The Conference recommends that at future Conferences the programme should include a greater proportion of time entirely free from pre-arranged business to enable delegates to have informal discussions

35. The Conference recommends that Commonwealth Entomological Conferences might sometimes be held in countries of the Commonwealth other than the United Kingdom, in order that delegates may be able to acquaint themselves with the research work in progress in such countries.

36. The Conference endorses the opinion expressed at previous Imperial Entomological Conferences as to the value of periodical meetings of entomologists and recommends that steps be taken in due course for a Sixth Commonwealth Entomological Conference to be held in 1953, of which long notice should be given, the place to be decided by the Executive Council of the Commonwealth Agricultural Bureaux.

APPENDIX I

Memorandum on the Work of the COMMONWEALTH INSTITUTE OF ENTOMOLOGY from 1st April, 1935 to 31st March, 1948

It has been the aim in the past to hold an Imperial Entomological Conference—or Commonwealth Entomological Conference as it is now called—once every five years. For obvious reasons it was not possible to hold a Conference in 1940 and thirteen years have elapsed since the last one. The difficulties arising during the war years resulted in a slowing up of the activities of the Institute but it is a matter for some satisfaction that our services to the entomologists of the Commonwealth were maintained unbroken throughout this period. Since the termination of hostilities, every effort has been made to recover lost ground and to develop the services that we render.

It has been customary to give a detailed review of the finances in the Memorandum on the Work of the Institute submitted to previous Conferences but, as these are now dealt with by the Commonwealth Agricultural Bureaux Conference, reference to them has been omitted here. The last such Conference was held in 1946 and provision was then made for the estimated financial requirements of the Institute for the ensuing five-year period. They will be reviewed again at the next Bureaux Conference in 1950.

Publications

Review of Applied Entomology

This monthly publication has made its appearance regularly, even during the war years when it often had to be prepared under exceptionally difficult conditions. It is now in its 36th volume and continues to be probably the Institute's most important production.

The amount of literature that came in during the war years naturally showed a sharp decrease but, once hostilities ceased, it increased again very rapidly and was augmented by a large volume of literature that had been published during the war in enemy or occupied territories. This exceptional volume of matter presented considerable difficulties because the number of abstractors had decreased as a result of retirements and resignations to take up war service. It has always been the policy of the Institute for the whole of the abstracting to be done by the permanent staff, with the exception of papers in Japanese which in any case lapsed during the war. Despite the fact that two new abstractors have been recruited it was inevitable that it would take some time to catch up in view of the spate of literature that had come in and the long time (at least two years) required to train an abstractor. The situation is now in hand and it is hoped that, by the end of 1948, the abstracting will be very nearly, if not quite, up to date once again.

It is necessary to point out that the tendency has been for the literature to become more difficult from an abstracting point of view and that the time required per abstract has therefore tended to become longer. This has been partly due to the highly technical nature of some of the articles dealing with insecticides of which there have been such a marked increase in the past few years following the discovery of DDT, benzene hexachloride and other new insecticides.

The number of subscribers to Series A and Series B and the total cash receipts from this source over the past 13 years are shown below.

		No. of Subscribers "A"	No. of Subscribers "B"	Total Cash Receipts £ s. d.
Vol. 23.	1935	571	436	1,282 17 5
" 24.	1936	588	447	1,440 12 3
" 25.	1937	603	442	1,595 18 11
" 26.	1938	637	464	1,429 9 8
" 27.	1939	664	475	1,386 12 6
		3,063	2,264	£7,135 10 9
				£ s. d.
Vol. 28.	1940	595	441	1,300 4 3
" 29.	1941	499	397	1,147 0 7
" 30.	1942	447	381	1,137 8 3
" 31.	1943	471	413	1,278 3 10
" 32.	1944	516	482	1,588 6 10
		2,528	2,114	£6,451 3 9
				£ s. d.
Vol. 33.	1945 ..	624	562	2,107 0 8
" 34.	1946	837	696	2,781 13 4
" 35.	1947 . . .	860	739	3,225 8 5

Whilst it was to be expected that the number of subscribers would fall during the war, the increase in the number since 1944 has been highly satisfactory. The figures for 1947 were not very far short of double the lowest figures recorded for 1942 and well in excess of any pre-war figures. Present indications are that the increased subscription rates that came into force at the beginning of 1948 have not resulted in any falling off of subscribers.

The total cash receipts show an even more striking rise than the number of subscribers and for the year 1947 the amount received was very nearly three times that for 1942. The greater number of subscribers only partly explains this increase, the difference being accounted for by the very heavy demand for back volumes. This demand can hardly be expected to continue at the present high rate and there may be some falling off in this respect within the next few years although no such tendency is at present discernible. Any such movement, however, will be offset to some extent by the fact that each year that passes adds another to the now considerable number of back volumes.

The volumes have varied in size considerably in the past 13 years but the average size, in number of pages, has been markedly less since 1942 than prior to that date. This discrepancy in size, however, is not so great as it appears because in 1942 the format was changed in such a way that the matter printed on each page was increased by about 12½ per cent.

Bulletin of Entomological Research

This quarterly journal has appeared regularly and is now in its 39th volume. The number of manuscripts received for publication naturally fell away during the war years but since the termination of hostilities the number has risen again and there are considerable delays in publication

This increase has been due in the main to three factors:—

1. The considerable amount of work carried out during the war, particularly in the field of medical entomology, that was written up subsequently and submitted for publication.
2. The marked increase in articles dealing with insecticides as a result of the very considerable developments in this field in the past few years. It is anticipated that the flow of such papers will be maintained or increased in the years to come.
3. The wide appeal of this periodical as a medium for publication.

The position at the moment is that there is a delay of at least 18 months between date of receipt and publication. This is unfortunate as in many cases it is desirable that the articles should appear with the least possible delay. This is especially the case with those papers dealing with the newer insecticides such as DDT and benzene hexachloride in which rapid developments are being made.

The size of the volumes has varied considerably during the past 13 years as will be seen below.

Years	*No. of Pages*	*No. of Plates*	*No. of Articles*
1935–39 (Average)	619	18	42
1940–44 (Average)	369	6	30
1945 (Vol. 36)	512	18	34
1946 (Vol. 37) .. .	632	9	44
1947 (Vol. 38)	622	11	43

The number of subscribers and the total cash received in respect of the *Bulletin* is tabulated below.

	No. of Subscribers	*Total Cash Received* £ s. d.
Vol. 26. 1935	381	820 7 5
„ 27. 1936	375	868 0 0
„ 28. 1937	386	812 0 9
„ 29. 1938	386	748 13 4
„ 30. 1939	407	719 8 11
	1,935	£3,968 10 5
		£ s. d.
Vol. 31. 1940 . .	385	746 3 7
„ 32. 1941	326	608 14 4
„ 33. 1942	297	568 14 4
„ 34. 1943	306	704 7 3
„ 35. 1944	353	982 6 3
	1,667	£3,610 5 9
		£ s. d.
Vol. 36. 1945	407	1,067 6 8
„ 37. 1946	520	1,711 8 2
„ 38. 1947	572	1,674 6 5

As was to be expected, the number of subscribers fell during the war, to just below 300, but since the war it has risen steeply and there is no indication at present that the increased annual subscription rate, that came into force at the commencement of the present year, has adversely affected the number of subscribers.

The increase in the total cash received has also been very marked since the war, the amount for the year 1947 being very nearly three times that for 1942. The lack of correlation between the receipts from subscriptions and the total cash received is explained very largely by the sale of back volumes which has been very heavy during the past three years. As in the case of the *Review* the same remarks concerning the future prospects for the sale of back volumes apply equally here.

Zoological Record

The "Insecta" part of this work, published by the Zoological Society of London, has been prepared annually by the Institute. Towards the cost of preparation it has been receiving £100 per annum and the major portion of the proceeds of the sale of the separate part amounting to £156 in 1947.

Sundry Publications

Two works have been separately published during the period under review as follows:

The Biological Control of an Insect in Fiji by Dr. T. H C. Taylor in 1937.

A Review of the Literature on Soil Insecticides by Dr H. C. Gough in 1945.

In accordance with past practice we have arranged for the publication of a number of papers by taxonomists who have described new species from material submitted to them by the Institute In the past seven years many taxonomic papers have been published by members of the staff in various scientific journals

Year	*No. of Papers*	*No. of Pages*	*No. of Staff concerned*
1941	27	349	7
1942	26	349	6
1943	26	643	5
1944	27	325	5
1945	10	279	5
1946	14	266	8
1947	15	422	5

The Library

Fortunately the library suffered very little damage as a result of the war. Only 36 volumes were lost—34 were burnt whilst at the binders (32 of these have been partially or wholly replaced, mainly by donation) and two whilst on loan in Leningrad.

During the period under review, the average annual growth has been 253 bound volumes, 931 pamphlets and 473 periodical publications Works issued on loan amounted to 880 annually.

The Library now contains some 11,700 bound volumes and 32,200 pamphlets. The author catalogue of monographs and separates is up-to-date and consists of some 140,700 cards, whilst the sheaf catalogue of serial and official publications amounts to about 4,200 slips.

Receipts of publications naturally fell during the war years, but the figures are rapidly approaching those for the peak year of 1935-36 despite the fact that many journals ceased publication in the intervening period. Every effort has been made to re-establish pre-war exchanges, the great majority of these have now been resumed and the gaps in the sets of periodicals filled

A feature of the Library's service before the war was the loan of books to workers abroad. This has now been largely replaced by the supply of photostats and microfilms of the works required by entomologists overseas.

There was a much increased demand for books on loan during the war, partly due to the fact that this was one of the few scientific libraries that kept its entire stock in London. In 1944-45, 1,308 works were sent out on loan; the corresponding figure for 1946-47 was 1,267.

Numerous visitors have worked in the Library, including representatives of Government Departments and scientists from the Dominions and Colonies, and a variety of enquiries have been dealt with, many of which were connected with the war effort.

During the post-war period, co-operation with the libraries of the other Agricultural Bureaux, the National Central Library and of other Institutions has been continued and expanded. Surplus publications have been sent to the Inter-Allied Book Centre to rehabilitate war-damaged libraries. A revision of holdings in the Library for the next edition of the "World List of Scientific Periodicals" has also been commenced.

Identification of Insects

The importance attached to this aspect of the Institute's activities was stressed at both the previous Conference and the Commonwealth Scientific Conference of 1936, and again at the Review Conference of 1946, when authority was granted for the appointment of two further specialists. These appointments were filled in October, 1947.

The number of identifications sent out in the past 13 years is given in the following Table:—

Year	Africa	America	Asia	Australia, New Zealand and Pacific Is.	Europe	Total
1935–36 ...	2,694	179	2,837	739	821	7,270
1936–37 ..	3,033	658	2,977	577	522	7,767
1937–38 ...	3,151	741	3,088	932	605	8,517
1938–39 .	3,304	618	3,539	1,223	811	9,495
1939–40 ...	3,290	297	2,860	966	368	7,781
1940–41 ...	2,621	49	2,099	406	112	5,287
1941–42 ...	1,508	14	561	378	118	2,579
1942–43 ..	1,211	12	107	427	91	1,848
1943–44 ..	1,881	108	196	291	428	2,904
1944–45 ...	1,698	93	447	263	343	2,844
1945–46 ...	2,144	270	758	573	514	4,259
1946–47 ...	3,847	401	1,025	628	353	6,254
1947–48 .	4,581	313	1,074	855	394	7,217

The material sent in for determination dropped off sharply during the war years, as was to be expected, but it will be noticed that the number of determinations sent out is now rapidly rising again. During the war, the fact that the British Museum collections in certain groups were evacuated for security reasons added to the difficulties of determination.

Four members of the staff are engaged full time on identification work, whilst three others devote a part only of their time to such work. Since the last Conference the Institute has suffered the loss of the services of two very valuable members of its staff. Mr. D. S. Wilkinson (Braconidae) was lost at sea whilst serving with the R.N.V.R. during the war. Dr. C. Ferrière (Chalcidoidea) resigned after the war to take up an appointment at the Geneva Museum.

Mr. G. E. J. Nixon was appointed in 1938 and is our specialist on the Braconidae and certain other groups of Hymenoptera and Mr. G. J. Kerrich was appointed in 1947 as the specialist in Ichneumonidae and Chalcidoidea.

Of the other permanent members of the staff, Dr. J. W. Evans has charge of the Homoptera, specialising in the Jassoidea. Dr. F. I. van Emden has charge of the Diptera and Mr. D J. Atkinson, who was appointed in 1947, is working on the Coleoptera. Dr. T. H. C. Taylor is in charge of the Lepidoptera and the Director of the Coccoidea.

The Institute is extremely fortunate in still having the invaluable assistance of Sir Guy A. K. Marshall, who has continued to deal with the Curculionidae, and of Mr. G. E. Bryant with his very wide knowledge of the Coleoptera. Dr A. P. Kapur, who is on a temporary appointment for four years (terminating next March), has charge of the Coccinellidae, and Mr. R. J. Collins, as a part-time worker, covers several sections of the Lepidoptera.

In some groups we receive much valuable assistance from specialists on the staff of the British Museum (Natural History) and we are glad to have this opportunity of recording our appreciation of their friendly and ever ready co-operation.

During the period 1935-1948, a total of 190,081 specimens has been presented to the British Museum, including 2,338 types of new species and 4,956 species not previously represented in the collections In addition, 15,453 specimens have been presented to other Institutions

General Information

A large number of enquiries have been dealt with annually covering a very wide field and often requiring considerable research. These include requests for advice on specific problems, research projects, references to published information on individual pests or classes of insects, information on taxonomic problems relating to insects of economic importance and many other subjects of an entomological nature

Accommodation

The Institute's activities are still greatly handicapped by lack of adequate accommodation, particularly for administrative and clerical staff in the Natural History Museum and for the library which is housed at 41, Queen's Gate. For some years past the need for additional library accommodation has been felt. That need has now become acute, but so far it has not been possible to find a satisfactory solution to this pressing problem.

APPENDIX II

PROCEEDINGS OF COMMITTEES

A. BUSINESS COMMITTEE

1. The Committee was constituted as shown on page 7.

2. The agenda placed before the Committee at its first meeting comprised the following items:—

(i) Consideration of a memorandum (Appendix I) by the Director on the work of the Commonwealth Institute of Entomology covering the period 1935-1948.

(ii) The *Bulletin of Entomological Research*.

(iii) Information on the morphology and physiology of insects.

(iv) Information on insecticides.

(v) Information on equipment for the application of insecticides.

(vi) The scope of the Institute's identification service.

(vii) The production of maps showing the distribution of insect pests.

(viii) The need for information to be available on the nature of research projects that are being undertaken or are in progress in the various countries of the Commonwealth.

(ix) Reviews of work submitted to the Conference.

(x) Any other business.

3. Items (iii), (iv) and (vii) arose from the report of the Proceedings of the Imperial Agricultural Bureaux Conference of 1946, and (ii), (vi), (viii) and (ix) were raised to ascertain the views of delegates on certain aspects of the activities of the Institute. Item (v) arose from the International Meeting on Infestation of Foodstuffs held in London in 1947, at which the difficulty of obtaining reliable and comprehensive accounts of equipment was mentioned. For the information of members of the Committee, memoranda on all these items were prepared and circulated in advance. Additional items raised under (x), after the commencement of the Conference, were: the subdivision of the *Review of Applied Entomology* into sections dealing with specialised subjects; the shortage of accommodation from which the Institute suffers; and the organisation of biological control work in the Commonwealth.

4. In his opening remarks at the first meeting of the Committee, the Chairman (Prof. J. W. Munro) asked Members to bear in mind that, owing to the war, an exceptionally long period had elapsed since the last Conference and that in the interim there had been a great increase in entomological activity and many changes in the organisation of entomological work.

5. Item (i) of the agenda was not separately discussed because the Committee felt that the principal matters in the Director's memorandum would be considered in the course of the discussions on the succeeding items of the agenda.

The Bulletin of Entomological Research

6. The reason for including item (ii) is apparent from Resolution 3. The memorandum dealing with the *Bulletin of Entomological Research* suggested four alternatives for accelerating the appearance of papers accepted for publication:

(*a*) Increasing the size of the *Bulletin* to, say, 800 pages per volume and the subscription rate to £3 per annum, while continuing to issue it quarterly.

(*b*) Increasing the size and price, but issuing six parts per volume instead of four.

(*c*) Splitting the *Bulletin* into two parts, one dealing with agricultural subjects and the other medical and veterinary, as in the case of the *Review*.

(*d*) Producing an entirely new journal for papers dealing with insecticides

7. The Committee discussed these alternatives very fully, bearing in mind that the *Bulletin* must continue to be a self-supporting publication. Various additional suggestions for relieving the pressure on it were made; these included the encouragement of the publication of papers of purely local interest in local journals, the exclusion from the *Bulletin* of papers on taxonomy and on ecological subjects, and the limitation of the length of papers submitted, but it was felt that although these measures would ease the pressure they would not do so sufficiently to solve the problem under discussion, especially as the number of papers produced by authors is likely to continue to increase for some years to come. It was also considered that issuing six parts instead of four would cause complications through overlapping during the preparation of successive parts, that it would not be practicable to arrange the papers into groups according to subjects for publication in separate sections, because many involve more than one subject, and that these procedures would cause unnecessary difficulties for the Editor and his staff. At the same time it was considered that alternative (*b*) providing for the issue of the *Bulletin* in six parts annually had much to commend it and that the possibility should be borne in mind should the present difficulties that make it impossible disappear. The question as to whether an increase in price would reduce circulation was answered by the statement that whenever one had been made in the past, either in the case of the Institute's publications, or for other journals produced by the Commonwealth Agricultural Bureaux organisation, circulation had continued to increase Resolution 3 resulted from this discussion.

Information on Morphology and Physiology

8. Item (iii) was fully discussed and the Committee unanimously agreed that the present coverage of these subjects in the *Review of Applied Entomology* is entirely satisfactory from the point of view of the great majority of economic entomologists (Resolution 4). It was explained in the memorandum on this item that papers dealing with physiology are always noticed in the *Review* if there is any evidence that they may have a bearing, direct or remote, on the bionomics or control of Arthropods of economic importance, and that morphological papers are considered for notice in the *Review* in relation to function and to the practical work of the economic entomologist, the object, in the case of descriptions of new forms or revisions of groups, being, not to reproduce or summarise these, but to inform the reader where he can find those that he requires. Furthermore, the *Insecta* part of the *Zoological Record* notices papers on the morphology and physiology of insects that are not of economic importance, and it is assumed that interested workers consult it as well as the *Review*.

Information on Insecticides

9. The information given on insecticides (item iv) in the *Review* covers their formulations, the rates, methods and conditions of their application, the degree of control obtained, their action on other insects and any other matters of practical importance, including highly specialised subjects such as the use of certain chemicals in a formula to facilitate penetration through the various layers of the insect cuticle and the mode of action of such chemicals. The Committee, after discussing the policy at present adopted in the *Review*, expressed complete satisfaction with it (Resolution 5).

10. The suggestion that abstracts dealing with insecticides should be issued as a separate section of the *Review* was made and carefully considered in this connection but was not favoured by the Committee (Resolution 6), because many papers concerned with insecticides embrace other topics in addition and because many groups of workers other than the insecticides group might also require separate sections. Mention was made of the fact that the *Review* is of value to chemists concerned with insecticides because it abstracts the papers in which they are interested from a different angle from that of chemical journals that cover the same papers.

Information on Equipment for the Application of Insecticides

11. Item (v) gave rise to considerable discussion. There was general agreement that there is an urgent need for information on equipment for the application of insecticides to be made more readily available, and the possibility of this subject being more fully covered in the *Review* was considered. The difficulties with which the Institute would be faced in attempting to satisfy this need fully were explained, and it was emphasised in the memorandum on this subject that all papers that deal with equipment for spraying or other similar purposes and are capable of being abstracted are already noticed in the *Review*, due attention being paid to any new principles that may be involved. The chief difficulties are that articles written primarily from the engineering point of view and usually illustrated, often with blue prints, cannot be abstracted without loss of essential details, and that the publication in the *Review* of accounts of equipment produced and described by commercial organisations is undesirable. The Committee welcomed the statement that the Inter-departmental Insecticides Committee is itself attempting to provide the information required and hopes to do so more fully in the future. Resolution 7 summarises the feeling of the Committee.

The Identification Service

12. The memorandum on item (vi) pointed out that the importance of the Institute's identification service had been stressed at previous Conferences. This service aims at the identification, for all countries of the Commonwealth, of Arthropods that are directly or indirectly important in connection with agricultural, medical, veterinary or other economic problems. It is difficult in practice, however, to restrict it within these limits, because it is impossible to lay down any definite rule as to what constitutes an Arthropod of economic importance. Moreover, some institutions and collectors in Commonwealth countries, and sometimes in foreign countries also, send their material to the Institute for identification, regardless of whether or not it is of economic importance, having discovered that they can thus get it named more satisfactorily than by sending it elsewhere. The material received can therefore be classified in several categories according to its source and degree of importance, and the highest priority is always given to material

justified and the maps would, in any case, be used with suitable caution and intelligence just as keys for identification are used. It was also suggested that lists of references would be preferable to maps, that maps should be accompanied by lists of references and by notes indicating whether the various references cited include information on bionomics, control and other relevant subjects, and that the production of maps should be a function of the information centre to be set up under the proposed African Quarantine Convention (see Resolution 27). The Committee agreed that if the maps were to be prepared by the Institute they would necessitate an increase in its staff, and that an increase of the staff for this purpose should be regarded as less important than any that might be proposed for the identification service. The recommendation that resulted from this discussion was adopted by the Conference as Resolution 11.

Information on new Research in the Commonwealth

17. Item (viii) arose from a suggestion that there is a need for entomologists in any one part of the Commonwealth, when embarking on a new project, to know whether work of a similar nature is in progress or contemplated elsewhere. The Business Committee of the 1935 Conference drew attention to this need, but with a rather more ambitious plan in mind than that outlined in the memorandum prepared for the present Conference, which merely suggested that each country should indicate periodically what specific problems are being investigated in it without any details as to methods, progress or results. The Committee agreed that this need exists and felt that the Institute is the right centre for receiving the proposed information and making it generally available. The question was raised as to whether annual reports could not serve this purpose, but the general opinion was that publication of them is often too long delayed and that they do not always mention new projects at their commencement. It was further suggested that if the Institute is to serve more fully than it already does as a centre for information of this kind, its staff should make more personal contacts by visiting the various Commonwealth countries from time to time. No very definite recommendations were made as to how this proposed information service should be operated, but the general feeling of the Committee is expressed in Resolution 12.

Accommodation

18. The problem of the acute shortage of accommodation that has faced the Institute for several years was carefully considered by the Committee. This has become increasingly serious until it is now one of the utmost urgency. It had been stressed previously by the Imperial Agricultural Bureaux Conference, 1946 (Recommendation xxvii, p. 11, of the report of that Conference). The Committee felt that, from the Institute's point of view, the only completely satisfactory solution would be for the staff (with the exception of some of its specialists) and the library to be accommodated on a floor of the new wing of the Natural History Museum, the erection of which was commenced before the war but has not yet been completed. While fully recognising that a decision on this matter must rest entirely with the authorities of the Museum, the Committee unanimously and emphatically expressed the hope that sympathetic consideration to the Institute's need in this respect would be given when or before the new wing is completed. The Committee was satisfied that the Executive Council of the Commonwealth Agricultural Bureaux has this pressing problem in mind and realised the Institute's need for expansion was a matter of extreme urgency. At the same time the great advantages enjoyed for so many years by the Institute in having

its Publication Office and Library in the same building as the Royal Entomological Society of London were fully appreciated. The Committee's views are summarised in Resolution 13.

Biological Control

19. The question of the organisation and development of biological control work in the Commonwealth was placed on the agenda of the Business Committee at the request of certain of the overseas delegates. A lively and profitable discussion took place, but there was a feeling of regret throughout the Committee that Dr. W. R. Thompson, F.R.S., Director of the Commonwealth Bureau of Biological Control, which, as the Imperial Parasite Service, moved to Canada early in the war years, was not present and that the discussion would have been even more valuable if the Committee had had the benefit of his advice and long experience in this field.

20. Several members expressed the view that there is a pressing need for research on biological control in many parts of the Commonwealth. The Indian sub-continent, Ceylon, East Africa, the African continent as a whole and the United Kingdom were specially mentioned in this connection. It was stated that the full scope of biological control is only beginning to be understood and exploited, and that the establishment of new permanent stations for the study of natural enemies and of their general importance as well as their actual utilisation for bringing about or supplementing the control of pests is urgently required. There was a feeling in the Committee that the United Kingdom is the right place for the Bureau of Biological Control, which should be a training centre as well as a centre for the distribution of beneficial insects to other countries, and one member expressed the view that the Bureau should be reabsorbed into its parent Institute. It was further pointed out that the majority of entomologists in the Dominions and Colonies visit the United Kingdom much more frequently than Canada, and when they do so many of them wish to discuss their problems in this field with the recognised authorities. In this connection, the Committee's attention was drawn to a recommendation of the Imperial Agricultural Bureaux Conference, 1946, to the effect that the Bureau of Biological Control should remain in Canada for another five years and that that Conference could see no reason why it should not stay there permanently, but in commenting on this, a member remarked that many entomologists were very disappointed when the Bureau went to Canada.

21. After some further discussion on the suggested new stations, and particularly whether they should be permanent or whether it would be preferable to attach the new entomologists concerned to existing institutions on a semi-permanent basis, the Committee recommended that the whole question of the organisation of biological control work should be referred to the next Commonwealth Agricultural Bureaux Review Conference due to be held in 1950, and that meanwhile a Committee should be appointed to prepare a memorandum for the Review Conference. It was suggested, pending approval in plenary session (which was subsequently obtained), that the membership of the Committee should be Mr. Gunningham, Dr. Le Pelley, Dr. Pruthi, Mr. Crawford, Dr. Miller, Dr. Jepson and Dr. Nicholson, and that Dr. Hall and Dr. Taylor of the Institute should attend the meetings but not as members. It was agreed that the first meeting of the Committee should be convened by the Institute at an early date, so that as many of the Members as possible could attend before returning to their respective countries, and that any business that might arise subsequently should be dealt with by correspondence through the Institute. Resolution 14 was the outcome of the discussion.

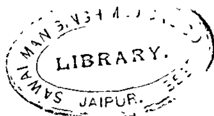
B. TERMITE COMMITTEE

This Committee consisted of eight members, as detailed on page 7, under the Chairmanship of Prof. J. W. Munro. Two meetings were held, at the second of which Dr. H. H. Storey, C.M.G., F.R.S., was also present. An opportunity to discuss the recommendations of this Committee and the summary on which they were based was given at the open meeting held on the afternoon of Thursday, 29th July. A summary of this discussion will be found in Appendix III on page 110. The recommendations of the Committee were submitted at the final meeting of the Conference and adopted as Resolutions 16 and 17.

C. COMMITTEE ON NOMENCLATURE OF INSECTICIDAL CHEMICALS

This Committee was set up as a result of the discussion on Insecticides held on Friday, 23rd July (page 35). It consisted of Dr. W. J. Hall (Chairman), Dr. W. Cottier, Dr. R. A. E. Galley, Dr. K. B. Lal, Dr. A. J. Nicholson, Mr. W. A. Ross and Dr. E. E. Turtle, M.B.E.

One meeting, which overlapped a meeting of the Business Committee, was held. Drs. Hall and Nicholson had to withdraw and the meeting continued under the chairmanship of Mr. Ross. The recommendations of this Committee were submitted at the final meeting of the Conference and adopted as Resolutions 19-23.



APPENDIX III

Proceedings of the Scientific Meetings

CONTENTS

MEETING: Friday, 23rd July, 10.30 a.m.

Chairman: Sir John C. F. Fryer, K.B.E., F.R.S.

Discussion: **Recent Developments in Insecticides**

The CHAIRMAN said that it was unnecessary to stress the importance of the subjects to be discussed. With the help of chemistry, great advances in insecticides had recently been made and we were faced with opportunities, but also with dangers, such as have never been apparent before. He called on Dr. R. A. E. Galley to open the discussion.

Dr. GALLEY: In opening this discussion on the recent developments in insecticides, I propose to review as much of the field as possible rather than deal more specifically with one or two special aspects, as this will, I feel, lead to a more general discussion of this rapidly expanding subject.

Since 1942, when DDT was introduced into Britain and the United States from Switzerland and when the insecticidal activity of benzene hexachloride had been recognised in Britain and, independently, in France, many thousands of compounds have been screened for insecticidal activity and considerable efforts have been expended, particularly in the United States, in attempts to prepare new compounds of high activity. In 1946, the results of German researches in this field became generally available in B.I.O.S. Reports Nos. 439, 1095 and 714 (revised), which were prepared by Oxley & Parkin (D.S.I.R.), Martin and Shaw (Long Ashton and East Malling Research Stations) and Mumford & Perrin (Ministry of Supply), respectively. Of the large number of compounds already examined, relatively few have been or are likely to be developed commercially, on account of difficulty or expense of manufacture, toxicity to the host plant or operator, or for other reasons.

I propose to deal first with the chlorinated hydrocarbon insecticides, of which DDT and BHC are the outstanding compounds

DDT AND RELATED COMPOUNDS

I shall say no more about DDT at this stage than that there is still a large volume of work in progress directed towards the preparation of improved formulations and methods of dissemination of the insecticide, concerning which we shall hear more this afternoon. Particular attention is being given to the question of the chronic toxicity aspects of DDT and BHC, a subject to which I want to refer again later.

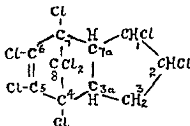
At least two compounds related to DDT have been produced on a fairly large scale in the United States, and one of them 1, 1-bis(p-chlorphenyl)-2, 2-dichloroethane, referred to as DDD or TDE, is sold under the name Rhothane in the U.S.A. It has been shown to be quite effective in the control of European corn borer and against stored-grain insects It is less toxic than DDT to higher animals, both as regards acute and chronic dosages. The other is the methoxy analogue of DDT, 1, 1-bis(p-methoxy phenyl)-2, 2, 2-trichloroethane, called by the Department of Agriculture "methoxychlor". The extent to which these compounds survive as competitors with DDT will depend upon their efficacy for special purposes.

We now come to BHC—benzene hexachloride or, chemically more correctly, hexachlorocyclohexane. As with DDT, a great deal of work is directed towards determining optimum rates and times of application and producing improved

formulations and methods of application. BHC has shown itself to be extremely efficacious in halting the ravages of wireworms, but in this connection the warnings, given by the manufacturers and Advisory Services, about tainting of root crops should be heeded. I hope that the discussion will reveal further information on the cause of the tainting, that is to say, whether it is due to an impurity or impurities in the product or to the decomposition of one of the isomers either before or after absorption into the root. During my recent visit to the United States, I was shown samples of alleged fairly pure γ isomer that had quite a pronounced odour, but which I was assured had been odourless when received a few months previously. This has not been my experience with a sample of γ isomer given by I.C.I. to Dr. F. N. Woodward during the war, in the days of the Insecticide Development Panel. If the tainting problem can be overcome, BHC will find even wider application than the already extensive use it now enjoys. It is very highly toxic to mosquitoes and tsetse flies in the form of contact sprays, residual deposits and smokes. Nearer home, it is most effective against household pests, for which a deodorised preparation is now on the market. Experiments are also in hand in which the purified γ isomer is being used as an ingredient of aerosol sprays for destruction of insects in aircraft.

Chlordane

Chlordane is the name given by the United States Department of Agriculture to the compound originally known as "Velsicol 1068" of empirical formula $C_{10}H_6Cl_8$. It is also known as "Octaklor" Information has been published concerning its structure, which is as shown below. The commercial product is a mixture of isomers and probably contains other compounds in addition. Chlordane



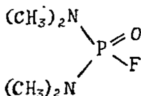
1,2,4,5,6,7,8,8-octachloro-4, 7-methano-3a,4,7,7a-tetrahydroindan

has been shown in the United States to be quite effective against Japanese beetle, pea aphis, Colorado beetle, body louse, American cockroach and the grasshopper. Ground applications of dust at 2—4 lb./acre of chlordane have successfully controlled chigger mites Samples of this material have been distributed to workers in this country and in Africa, and I hope that some observations on its efficacy or otherwise in the problems to which it may have been applied will be forthcoming during the discussion.

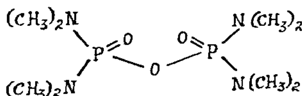
One of the firms producing this compound has recently announced two new insecticides, one of which has been called "Heptaklor" and the other Compound No. 118 The latter is stated to be an alkali-stable chlorinated compound, of which I was able to obtain a sample, but no information about its structure or activity. No definite information is available about the former, except that it was isolated originally from the crude Octaklor, but is now made as a specific product. It, too, is almost certainly a mixture of isomers. From this information and from its name, one would be led to believe that it is a compound of structure similar to

Reference to absorption brings us to a special group of insecticides that Schrader called agents for plant chemotherapy. Martin, who has substantiated Schrader's claims for some of the compounds, has called them the systemic insecticides. In the main, the compounds found by Schrader to possess this property of absorption by the plant, either through the leaves or roots, are too toxic to higher animals *to be used commercially. Obviously work in this field will be intensified to find* good insecticides of lower mammalian toxicity, as compounds of this type would appear to possess advantages not possessed by other stomach poisons, one in particular being their translocation to all parts of a growing plant, which offsets irregularities of the original application.

Compounds shown to possess systemic insecticidal properties are the fluorine compounds, bis(β-fluoroethoxy) methane, $CH_2(OCH_2CH_2F)_2$, and its higher homologue bis(β-(β'-fluoroethoxy)ethoxy) methane, $CH_2(OCH_2CH_2OCH_2CH_2F)_2$, and one that contains both phosphorus and fluorine, bis(dimethylamino) fluoro phosphine oxide.



The phenomenon is also exhibited by the pyrophosphoric acid derivative, the structure of which is—



Dr. Hubert Martin has been active in this field and will, I hope, give us some details of his work in the course of the discussion.

A short time ago, I said that I wanted to refer to the toxicity to mammals of these new insecticides The tendency, with the introducion of the phosphorus compounds, has been towards more highly toxic substances, a tendency that is deplored by the toxicologists The risks to operators by dermal absorption are *real, and precautions in handling and use will have to be undertaken intelligently.* In addition, times of application will have to be worked out so that no dangerous residues from the more stable compounds are left on food at the time of harvesting or consumption. Data are being collected on these aspects, but more work is required, particularly on the chronic toxicity of the newer materials, before final recommendations can be made concerning their use. The effects of continued ingestion of small amounts of DDT and BHC are being determined in experiments now in hand at Weybridge and Porton, and we hope that before long facilities will be available for more detailed experiments on the toxicity of the phosphorus compounds to supplement those already carried out at Porton and by Bergen and Keene at Middlesex Hospital

The fact that most of the synthetic insecticides possess a toxicity hazard prompted workers in the United States to investigate more thoroughly the possibility of activating and stabilising the unique insecticide, pyrethrum. These investigations have resulted in the production of the compounds known as piperonyl butoxide and piperonyl cyclonone. Although the claims of the manufacturers as regards synergism have been substantiated by the U.S. Department of Agriculture and other official laboratories, those concerning the stabilising power, *i.e.*, the power of giving residual deposits with pyrethrins equal to those obtained with DDT, have not. The claims in this connection were that a deposit of 50 mg./sq. ft. of piperonyl butoxide and 2·5—5 mg./sq. ft. of pyrethrins gave a greater residual effect against *Calandra granaria* than 200 mg./sq ft. of DDT. I understand that the results of such experiments as have been carried out in this country are in accord with the official U.S. results. It is apparent, however, that researches in this field should be extended.

Harper and his colleagues, working in London on the structure of pyrethrins and attempting to determine the part of the molecule responsible for the spectacular knockdown associated with this insecticide, have prepared two series of pyrethrin/DDT hybrid molecules, which have been tested for knockdown by the Pest Infestation Laboratory. The first series consists of the substituted phenyl and ethyl esters of the dl, cis and trans chrysanthemum monocarboxylic acid portion of the pyrethrin molecule, and the second of derivatives of the cyclopentenone portion of the pyrethrin molecule.

I think I am correct in saying that no compound has yet been prepared which gives high knockdown, but if he is here, Dr Harper may be able to correct this statement, and to indicate any new types of compounds that he may now have under test.

I am conscious that I have not dealt with developments in fumigation or mentioned several interesting compounds, including benzyl benzoate, benzil, diphenyl carbonate, bis(p-chlorphenoxy) methane, the various salts of dinitro-o-cyclohexylphenol and many others, and I hope that contributions on some of these will follow, but before I close, I want to refer briefly to a question that has resulted from the introduction of these new compounds, *i.e.*, that of nomenclature.

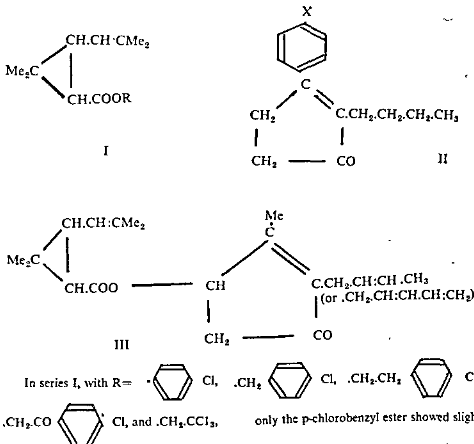
You will have noticed that I have referred to names given to insecticides by the U.S. Department of Agriculture In discussions with the Chairman of the U.S. Committee that considers nomenclature, we agreed that it would be desirable to have names in which we, as a Commonwealth, concurred, and I said that I would ventilate the question during this Conference. I also spoke to the New Zealand representative at the British Commonwealth Scientific Office in Washington, who has prepared a paper on the subject, and I would suggest that this would be a reasonable subject for discussion here and later in committee. It should be possible for us to devise a means by which we could work with the United States on this matter of nomenclature, and thus avoid the confusion that will occur if a compound is given a variety of names in different parts of the world.

Dr. Hubert MARTIN said that it was necessary to correct confusion with regard to claims about systemic insecticides Their property was novel in that they were absorbed by the plant through the soil and reached the growing point with startling rapidity (less than 24 hours). The concentration must be carefully controlled because of phytotoxic action. They had an intense fumigant action. Willow cuttings were allowed to shoot in water culture, the rooted cuttings put in the systemic insecticide until they had absorbed a known amount and then

returned to water culture. They were left for about four days in an attempt to avoid fumigant action, and were then infested with brassy willow beetles. These were dead within 12 hours with practically so sign of feeding. The next step would be the use of a radioactive compound to trace the course of the insecticide through the plant. Systemic insecticides were highly toxic and therefore difficult to obtain. It would be a calamity to depend on commercial production, and wrong to allow them to come on the market until more about their properties and hazards had been ascertained.

Dr. S. H. HARPER said that following the synthesis of chrysanthemum monocarboxylic acid, tetrahydropyrethrolone, dihydrocinerolone, and several hydrogenated pyrethrin Is (Harper *et al.*, *J. Chem. Soc.*, 1945, 283; 1946, 892. *Nature*, 1948, **162**, 222), it had seemed of interest to prepare pyrethrin-DDT hybrids. The insecticidal activity of these hybrids might throw light on the mechanism of the action of the pyrethrins or of DDT, and moreover might give a substance with the high knockdown effect of the pyrethrins combined with the lethal effect of DDT.

To date two short series of compounds had been prepared and tested against house-flies; they are represented by I and II, pyrethrin I being III.



In series I, with R= $\cdot C_6H_4$ Cl, $.CH_2 C_6H_4$ Cl, $.CH_2.CH_2 C_6H_4$ Cl, $.CH_2.CO C_6H_4$ Cl, and $.CH_2.CCl_3$, only the p-chlorobenzyl ester showed slight knockdown and moderate kill; while in series II, with X=H, Cl, and Br, none showed any significant knockdown or kill. It would be premature to draw any conclusions from this limited amount of data.

The insecticidal tests were carried out at the Pest Infestation Laboratory through the courtesy of Dr. E. A. Parkin.

Mr. W. A. Ross suggested the appointment of a committee to collaborate with American workers in choosing common names for new insecticides.

Dr. W. COTTIER supported this. He said that he had received a letter on the subject from the Scientific Liaison Officer in Washington. Although exact chemical terminology was desirable from the scientific point of view, there was also a need for simple names specific for economic poisons, because chemical nomenclature was too cumbersome for discussion, reports of field treatments and memoranda, and difficult for non-chemists, and, in the absence of popular names, varied trade names were being used.

Dr. E. E. TURTLE also supported the proposal, stating that confusion among compounds had already arisen. After some further discussion, a Committee of seven,* with authority to co-opt, was appointed by the Delegates at the meeting.

Mr. C. T. GIMINGHAM said that Dr. Galley's brief and skilful review of modern insecticides, and the American literature, were both bewildering. Systemic insecticides were a remarkable new discovery, but their physiological and toxic properties were so little known that further investigation was imperative.

Discussion: Mode of Action of new Insecticides

The CHAIRMAN called on Dr. V B Wigglesworth to open the discussion.

Dr. WIGGLESWORTH: The "mode of action of insecticides" signifies something different for different people. Those concerned immediately with the practical use of insecticides are most interested in the manner in which the poison is picked up by the insect Those who look a little more deeply into the subject are occupied with the problem of the entry into the insect. Finally we are faced with the problem of how the insecticide intervenes in the vital processes in the tissues. Taking DDT as the insecticide, we may consider a few examples of its mode of action at these different levels of enquiry.

(i) The work of David & Bracey has shown how insecticidal mists are picked up by the insect. Movement is necessary for the impaction of the droplets. This takes place particularly on the beating wings, and the insecticide is transferred to other parts when the insect cleans itself. The final site of entry remains to be investigated The properties of residual films of DDT are important in this connection. Parkin & Green made the surprising observation that the toxicity of supersaturated solutions in oil increases greatly when they crystallise. Barnes found that large particles of DDT in distemper are the most effective and McIntosh that in watery suspensions large elongated crystals gave the highest kills. Yet the presence of a little oil is said to make DDT dusts more active.

(ii) There is no really clear evidence of just where DDT enters through the cuticle. Hayes & Liu have found that entry through the feet is much more rapid in *Musca* than in *Epilachna* or *Blattella*, and this is correlated with a thinner tarsal cuticle and the presence of thin-walled chemoreceptive sensilla. The entry of DDT through the insect cuticle is extraordinarily efficient and probably accounts

* See p. 26.

for the excellence of DDT as an insecticide, for there is little difference in toxicity to different animals if it is injected into the body fluid. In the cockroach, the LD 50 is about 8 mg./kg. body weight on injection, and 10 mg./kg. on surface application.

(iii) The most obvious effect of DDT after absorption is on the nervous system, causing over-excitability and incoordination. The study of muscle-nerve preparations in Crustacea by Welsh & Gordon has shown that DDT, like many other substances, produces repeated volleys of impulses causing tetanic contractions in the muscles. Whether the site of action in the intact insect is on the motor or the sensory fibres or on the central mechanism seems to depend upon the species of insect and the dosage. The most obvious explanation of death from DDT poisoning is the exhaustion of reserves following upon this excessive activity. But, as Tobias and his colleagues have shown, the course of poisoning *is not altered by anaesthetics that* suppress the movements or by the administration of glucose. The action of DDT on the nervous system is largely determined by the lipoid solubility of the molecule. If the chloroform residue is replaced by something water-soluble, it becomes inactive. Welsh and Gordon conclude that it is mainly a question of adsorption in the nerve fibre. (Both entry of DDT through the cuticle and action on the nervous system show a negative temperature co-efficient, which suggests surface action of some kind.) These authors even explain the significance of halogenation on a physical hypothesis, arguing that it is a question of obtaining a molecule of high density that will not be too mobile after adsorption

But there is a great reduction in activity if the chlorine atoms on the benzene rings are moved from the para-para position, which suggests that the shape of the molecule is important Busvine has postulated a steric association with some enzyme, and Munson & Yeager have suggested that this might be the cytochrome oxidase system. Up to a point, as Martin & Wain have shown, there is a rough parallel between the activity of chemicals related to DDT and the ease of dehydrochlorination, and they have therefore suggested that these substances owe their activity to the release of hydrochloric acid when adsorbed at the sensitive interface. Although there are exceptions to this rule, the hypothesis of Martin & Wain has provided a useful guide in the search for chlorinated ring compounds with insecticidal properties

The CHAIRMAN said that the points discussed were not only scientific but extremely practical. Insecticides had previously been discovered largely by chance, but a logical method of search for them should now be possible.

Dr. W. F. JEPSON asked what was the essential difference in action between benzene hexachloride and DDT. On white grubs and relapsing-fever ticks, benzene hexachloride acted more intensely and effectively than DDT. White grubs shrivelled after exposure to its vapour, so that its effect seemed to be dehydrating. Did this indicate penetration of the cuticle?

Dr. WIGGLESWORTH replied that the effect of benzene hexachloride on wireworms seemed to be on their behaviour; they do not feed or look after themselves as they would normally Possibly white grubs suffer in the same way, not looking after themselves and so allowing themselves to dry up. Scratching of their cuticle by soil particles would increase its permeability.

Dr. JEPSON agreed that this explanation was probably correct, since no direct effect on white grubs could be observed during the process of poisoning.

Dr. D. W. WILLIAMS referred to the differences between insecticides in their effect on different species or stages of insects. Pyrethrum was equally effective against *Tribolium* and *Rhizopertha*, while benzene hexachloride was not; and

pyrethrum killed both larvae and adults of the flour moth, whereas benzene hexachloride and DDT killed the adults and not, except at high concentrations, the larvae. Differences in permeability of the cuticle might not be the sole explanation of these differences.

Dr. WIGGLESWORTH thought that it might be a matter of entry rather than of inherent susceptibility. The question of entry was subtle and affected by factors of behaviour, anatomy and physiology.

Dr. A. E. CAMERON asked what was the effect of systemic insecticides on insect tissue and also whether there was any indication of differential activity of insecticides such as DDT on nerve tissue or nerve sheaths. Work in the United States had indicated that DDT accumulated in the adipose tissue of mammals. This suggested the possible risk of poisoning by DDT in the meat from animals that had ingested it with their food. He referred to Lauger's theory that the chloroform part of the molecule was responsible for penetration and allowed the chlorbenzene part to act, presumably by destruction of nervous tissue.

Dr. WIGGLESWORTH said that DDT concentrated in the nervous system and produced effects before histological effects were discernible

Dr. R. L. WAIN said that Dr. Wigglesworth had suggested that if the $CHCCl_3$ in DDT were replaced by a more water-soluble radical, the compound became less toxic. However, if it was replaced by $CClCCl_2$, with even less water solubility, the compound was not toxic This fitted with the theory that HCl is responsible for toxicity So many compounds were active that it was difficult to postulate a common factor unless it was very simple. It appeared probable that if HCl was carried in an organic molecule to a vital point it would be effective, but the conditions could not be reproduced by trials with HCl itself. The activity of the γ isomer of benzene hexachloride fitted with this theory. DDT and BHC persisted for long periods in the soil without breaking down and BHC affected plants. The enthusiasm with which it was being used by growers for wireworm control involved the risk of an increase of concentration until plant growth would be affected. In his experiments, systemic insecticides had not given spectacular results; they had injured plants and yet caused little mortality of insects on them.

Dr. Hubert MARTIN congratulated Dr. Wigglesworth on the differentiation of the three aspects of toxicity, and pointed out that bio-assay tested two of them (absorption and activity inside) at the same time. If it became possible to measure the effect of the chemical on the vital point, clearer results would be obtained Assuming that DDT was absorbed and possibly concentrated at the site of action, the para chlorine atoms were apparently important They could be replaced by the methoxy radical or H, but when OH was substituted the compound did not concentrate at the site of action. The compound was not insecticidal when the aliphatic chlorines were replaced by radicals such as methoxy, or the hydrogen by chlorine. This gives a clue to the importance of HCl.

Dr. F. I VAN EMDEN asked whether strains of insects resistant to highly complex insecticides had developed? He had heard of their development in *Musca domestica* and *Culex molestus.*

Dr. WIGGLESWORTH replied that the classic examples of development of resistance were to simple inorganic compounds, but there was a rumour of some flies in Italy that were resistant to DDT.



The most serious complication arising from the use of DDT is the drastic effect on biological balance resulting from its great toxicity to most insect predators and parasites, with the result that insects and mites hitherto of little or no importance may soon reach destructive numbers following its application. While DDT may occasionally cause minor outbreaks on herbaceous crops, for example of Aphids on cabbage, such infestations are much more serious on woody plants with their generally more complex fauna. In British Columbia, the woolly apple aphis (*Eriosoma lanigerum*), which has been of little importance since the establishment of its parasite, *Aphelinus mali*, nearly 20 years ago, has in some instances become injurious where DDT has been used for codling-moth control.

Much more destructive are the outbreaks of mites that have almost invariably followed the employment of DDT in orchards throughout North America. In Canada, the species concerned are European red mite (*Paratetranychus pilosus*) in the east, and this species and Pacific mite (*Tetranychus pacificus*) in British Columbia. Studies in Ontario peach orchards have shown that DDT completely eliminates all important predators of the European red mite, including various mites of the genus *Typhlodromus* (*Seiulus*), the Coccinellid, *Stethorus punctum*, and the thrips, *Haplothrips subtilissimus*, and similar investigations in Nova Scotia have proved it to have the same effect on the red-mite predators occurring there on apple. Incidentally, the Nova Scotia investigations form part of a long-term project to evaluate the effect of various spray materials on the orchard fauna. Among the valuable information already obtained is that even materials formerly thought to be comparatively innocuous, such as elemental sulphur, may profoundly depress biological control agencies and thus promote outbreaks of certain pests.

Examples of the resulting complexity of spray programmes are those necessary where DDT must be used for codling-moth control. The addition of an acaricide is always needed in two or more of the cover sprays, and in the east lead arsenate must also be included for apple maggot (*Rhagoletis pomonella*), because DDT has not yet been shown to give the very high degree of control of this pest required on apples intended for the overseas market. We are also anxious to avoid the losses caused in neighbouring parts of the United States by the red-banded leaf-roller (*Argyrotaenia velutinana*) when lead arsenate was omitted from the programme. In Southern Ontario, alternating cover sprays of DDT and of lead arsenate with summer oil have furnished satisfactory control of all apple pests. In the cooler sections of the Dominion, where lead arsenate will give reasonable control of codling moth, DDT is not recommended on apples.

The caution necessary in advising the use of DDT is exemplified by the problem of the oriental fruit moth on peaches in Ontario. For about 15 years parasites, both native and introduced, have usually given good control, but in occasional seasons or in certain localities serious outbreaks have occurred. DDT is quite effective against the fruit moth, but unfortunately it is also exceedingly toxic to the parasites. We fear that the indiscriminate use of DDT on peaches might start a vicious circle, in which general spraying might release the moth from the pressure of parasites and so require still more and more spray applications for moth control. At present we are advising a programme of as few and as late applications as possible, designed to supplement natural control instead of conflicting with it.

Analogues of DDT

The two commercially available DDT analogues, 2,2-bis(parachlorophenyl)-1,1-dichloroethane and 2,2-bis(paramethoxyphenyl)-1,1,1-trichloroethane, have had very little testing and no practical use in Canada. They appear effective against a considerably narrower range of insects than DDT, but their distinctly lower toxicity to higher animals may fit them for some special purpose.

Although it is undoubtedly one of the most potent insecticides, the practical development of benzene hexachloride in Canada has progressed much more slowly than that of DDT, chiefly because of the tendency of commercially available formulations based on crude compounds to impart an objectionable flavour to fruits and vegetables, and also to some extent because of their phytotoxicity. Where benzene hexachloride can be used at all, it must be applied in a precise manner based on careful research; the careless use that has characterised some of the applications of DDT would be disastrous in the case of benzene hexachloride. Whether the employment of high gamma materials will eliminate the effect on flavour remains to be seen. If it does not, it is difficult to see any future for this insecticide in the control of fruit and vegetable insects.

In applications for the control of soil insects, a field in which benzene hexachloride appears to have greatest usefulness, it has been found that proper placement and rates of application must be followed to avoid plant injury. It would seem advisable to use it with caution until more is known about possible effects on soil fertility through its possible destruction of micro-organisms. On foliage it may usually be employed with a reasonable margin of safety except on some susceptible plants such as cucurbits and maize.

Samples of different fruits sprayed with benzene hexachloride and identified only by number were submitted to a panel of dieticians in the Department of Agriculture for flavour tests in the raw condition, after stewing in open kettles, and when canned. In most cases the flavour of raw fruit sprayed an appreciable time before harvest was not affected, although Italian prunes sprayed 19 days prior to sampling were objectionable. When stewed, a musty or otherwise abnormal flavour was sometimes present, even when not noticeable in the raw state, and a musty odour was often given off during cooking. In the canned product, tainting was much more pronounced, over 80 per cent of all samples being objectionable in this state For example, Bartlett pears sprayed twice with 2 lb. crude benzene hexachloride per 100 gals., the last application 60 days before harvest, had a disagreeable flavour after being canned, and tainting was also pronounced in plums sprayed once 44 days previous to harvest

When peas were treated with benzene hexachloride for Aphid control, a musty flavour was present immediately after they were canned but later disappeared. This was not true in the case of fruits, which were not tested until three or four months after they were canned

Potatoes are so susceptible to tainting from either soil treatments or foliage applications that benzene hexachloride definitely cannot be employed on them When they were grown on soil treated over a year previously with crude benzene hexachloride at 7·5 lb. per acre, the tubers were inedible No tainting has been detected in tomatos or tobacco grown on soil treated with this insecticide for wireworm control.

One of the few uses for which benzene hexachloride is now recommended in Canada is for control of wireworms in tobacco fields, where it can be conveniently applied by mixing it with the fertiliser. It will doubtless prove useful against wireworms on other crops where tainting is not a problem, but whether its cost will permit its general use on field crops such as wheat appears doubtful unless seed treatments prove to be satisfactory. In preliminary experiments in British Columbia, it gave very good protection to strawberries against the attacks of white grubs (larvae of *Polyphylla perversa*)

For grasshopper control under Canadian conditions, benzene hexachloride has proved inferior to some other new insecticides because of its lack of residual toxicity.

If the problem of tainting can be overcome, benzene hexachloride will be valuable for the control of soil-infesting insects in general and a number of fruit pests. It is very effective against various species of Aphids, its toxicity being greatly increased when it is used in 0·5 per cent. light oil emulsion. Summer sprays of benzene hexachloride in light oil emulsion afford good control of pear psylla, and in dormant sprays in oil emulsion it gave promising experimental results against peach twig borer (*Anarsia lineatella*) and eye-spotted budmoth (*Spilonota ocellana*).

In our early experiments, benzene hexachloride appeared relatively ineffective against adults of the plum curculio (*Conotrachelus nenuphar*) because of its lack of residual toxicity. More recent work in the United States has indicated that it will destroy the larvae within the fruit, and it has been used in the middle and southern states where this insect is very destructive to peaches. During the present year, however, some canning companies have announced that they will not accept peaches sprayed at any time with benzene hexachloride because of the danger of tainting.

CHLORDAN

Chlordan (formerly known as chlordane), 1,2,4,5,6,7,8,8-octochloro-4,7-methano-3a,4,7,7a-tetrahydroindan with related compounds, appears to have little place in fruit insect control, but is the most effective of the newer insecticides against grasshoppers, acting chiefly as a food-plant poison with a comparatively long residual effect. Application at 1 lb. per acre in oil solution has given excellent results, but its use is still in the experimental stage. In Canada, the new insecticides applied as sprays or dusts do not seem to have any great advantage over the old baits, under conditions where the latter can be expected to succeed. The possibilities of chlordan and benzene hexachloride as toxicants in baits are under investigation.

Among other uses, chlordan has some promise for the control of soil insects.

CHLORINATED CAMPHENE (Toxaphene)

Little or no practical use of chlorinated camphene has been made in Canada. In oil sprays it has given fair results in grasshopper control but is apparently less effective than chlordan. Chlorinated camphene has given reasonably good experimental control of orchard mites in British Columbia when applied in conjunction with summer oils.

TETRAETHYL PYROPHOSPHATE

Tetraethyl pyrophosphate, including so-called "hexaethyl tetraphosphate," in which the former is the principal component, has a very limited field. It may have some value as an emergency spray against Aphids, immature stages of scale insects, etc., but in the control of orchard mites its lack of ovicidal or residual action makes the timing of the sprays too critical for practical orchard use. Its high toxicity to mammals is also a serious limitation.

Recent experiments, still being continued, have demonstrated that a combination of TEPP with the monoethanolamine salt of dinitro-ortho-cyclo-hexylphenol possesses outstanding ovicidal value against the eggs of two-spotted mite (*Tetranychus bimaculatus*), whereas either material alone has little effect on the eggs.

BIS-(PARA-CHLOROPHENOXY)METHANE

Because of the great increase in the importance of orchard mites following the use of DDT, the search for efficient acaricides is now one of the major problems of fruit-insect research in Canada. Among the better materials investigated so far is bis-(para-chlorophenoxy)methane, which is toxic to both eggs and active stages of all important species of orchard mites. It is compatible with all other

spray materials commonly used on fruit trees in Canada, and in local work has produced no injury on apple, plum, peach and bean, but elsewhere it has caused quite severe russetting on apple and pear.

The possibilities of low concentrations of this material in combination with dinitro-ortho-cyclohexylphenol acaricides are being investigated, in the hope that such a mixture would eliminate the danger of fruit russetting from the former and foliage injury from the latter.

Diparachlorophenylmethylcarbinol

Diparachlorophenylmethylcarbinol, or 1,1-bis(para-chlorophenyl)ethanol, was one of the most promising acaricides in laboratory tests, possessing great residual and ovicidal effects. Orchard trials in British Columbia also gave very good results. This material is apparently difficult to manufacture, so that its cost may be excessive.

Salts of Dinitro-ortho-cyclohexylphenol

Dinitro-ortho-cyclohexylphenol is not a new insecticide and its dicyclohexylamine salt has been rather widely used in Canada for orchard-mite control, usually with erratic and often unsatisfactory results, especially at low temperatures. Research by Canadian workers has shown that other salts are more effective. The monoethanolamine salt is probably the best acaricide now readily available in Canada and is being generally recommended for use on apples.

Ethylene Dibromide and D-D Mixture

Ethylene dibromide (20 per cent by volume) at 5 to 8 gals. per acre (depending on soil temperature) has proved highly effective and advantageous against wireworms in several large-scale field tests in various parts of British Columbia; and has shown much promise in field experiments against white grubs. It is being employed by growers to a considerable extent in wireworm-infested land used for potatoes and other truck crops. The savings there effected well repay the cost, which at present runs from $20.00 to $30.00 per acre for materials. Dichloropropane-dichloropropene mixture at 16 gals. per acre has shown similar experimental promise against both wireworms and white grubs, but its practical use has been limited by its much higher cost (approximately double) and somewhat greater hazards. Home-made plough-applicator equipment makes it both simple and very inexpensive to use these liquid fumigants.

Parathion

Canadian investigations on parathion (0,0-diethyl-0-para-nitrophenyl thiophosphate, 'E605', '3422') are still very much in the preliminary stage. Laboratory and some very limited field tests have shown its extremely high toxicity to a wide range of fruit and vegetable insects. In our early experiments, failure to appreciate its great potency resulted in the loss of many cultures of test insects in the greenhouse. Precautions followed in experiments with DDT and benzene hexachloride were quite inadequate in the case of parathion, and the most rigid isolation of rearing cages from spraying operations and treated plants and soil was necessary. The presence of a few plants sprayed with parathion frequently caused high mortality of Aphids on untreated plants in the same greenhouse compartment.

In the still air of a greenhouse compartment, parathion at rates as low as 0·009 lb. per 100 gals. gave virtually complete mortality of the green chrysanthemum aphis (*Rhopalosiphum rufomaculatum*) and nymphs of pear psylla, but approximately twice that concentration was required to produce equivalent mortality of the Aphid in an air current of about three miles an hour. At comparatively high concentrations, parathion may function as an ovicide, 0·45 lb. per 100 gals. giving 100 per cent. mortality of pear-psylla eggs. Small-scale orchard



Dusts by their physical nature are not well suited for the satisfactory application of insecticides and fungicides. In a few special cases when the host-plant or target is well adapted to retain a dust, they are equal in efficiency to washes, for example an application of DDT to the soil for flea-beetle control and derris for the control of raspberry beetle. The amount of the active material added to an inert diluent and the weight applied per acre are adjusted in the case of fungicides to avoid damage to the host-plant, though in many cases the lack of adhesion plays the greater part in providing a safety factor.

The application of small droplets of concentrated materials has attracted attention for many years. In theory it appears easy to achieve, but in practice on crops it is most difficult. The first difficulty is the need to avoid over-application, especially of present-day fungicides and of oils with which the risk of damage to the host-plant is considerable. Over-application on some portions of the target is often unavoidable if an adequate deposit on another portion is to be obtained. The dangers of over-application may in time be of little consequence owing to the development of new materials. The second major difficulty is to propel small droplets to the target. The difficulty becomes greater with increase in the height of the crop, the density of the foliage and the velocity of the wind. The small droplets are generally required to remain on the spots they contact, or if individual droplets unite they should not do so to the extent of causing any "run off".

I am leaving the subject of the application of aerosols on field crops to Dr. Berkeley, as this method of application is still very much in the experimental stage in this country. The little I have seen of it suggests that the same difficulties will be met as are experienced in propelling small droplets to the target.

Equipment

The development in equipment during the past few years has been mostly in improvements in detail design and lay-out rather than in entirely new principles. These improvements, though of little interest to most entomologists and mycologists, are of the greatest consequence to the user, as they make all the difference between success and failure in control measures.

It is convenient to divide equipment into two groups (*a*) hydraulic and (*b*) air-flow.

Hydraulic Equipment

The type of hydraulic equipment used varies in different parts of the world according to the cost of labour and nature of the crop. Thus in India the battery type of knapsack is the standard type, even on large tea estates; such a method of application appals all of us used to power equipment, nevertheless under the existing methods of culture and cost of labour it is economic. It would appear that there is still a big field for well designed and reliable knapsack and other types of manually operated equipment. The simplicity of the equipment is well suited to native labour. Unfortunately, much of it is of poor design and no effort has been made to standardise such items as nozzles, lances, threads or spares. This unfortunate state of affairs could be readily altered if the purchaser ordered his equipment to a specification and was prepared to pay for better quality.

Several interesting hydraulic pumps have been developed in England since the war, ranging from low-pressure centrifugal acid-resistant types operating at 30 lb. per sq. in. to plunger pumps operating at up to 650 lb. per sq. in. The low-pressure centrifugal pumps are reasonably well suited for spraying ground crops with a "boom", but for the application of small volumes of small droplet size a much better performance is obtained from 75 lb. per sq. in. This small increase in pressure greatly facilitates the design of a simple nozzle.

High-pressure plunger pumps, operating at 400 to 650 lb. per sq. in., of compact totally enclosed, self-lubricated and readily serviced type, are now available in this country. Most of them are of the three-throw short-stroke type, operating at about 150 strokes per minute. The pressure controllers on some models, like those on some American machines, are still inefficient and do not allow of the use of the pump to full advantage.

The Ministry of Agriculture* has published a broad specification for pump design and it recommends that four capacities of pump will meet the requirements of fruit growers; the sizes recommended are 3—5, 10, 20 and 35—40 gallons per minute delivery at a working pressure of 400 lb. per sq. in. with a maximum of 650 lb. per sq in. (3—5 g.p.m. 300 lb. per sq. in.). This range of pump sizes satisfies most spraying requirements

Improvements have been made in the design of nozzles and their assemblage on "broom heads" to suit different crops. Much of the work has consisted in tidying up the designs so that the maximum performance can be obtained with the minimum of fatigue for the sprayman. It would seem probable that the end-point in the design of lance equipment has been reached.

The efficiency of lance spraying depends not only on design but very largely on the skill of the sprayman; his difficulties increase with the height and density of the crop The greatest waste of wash occurs with large standard trees and the least on bush crops.

The toil, expense and variable personal factor of efficiency associated with lance spraying have turned attention to so-called automatic spraying. This method consists of trailing a spray machine over or past the crop. Adequate "coverage" of a ground crop is fairly readily obtained by automatic spraying, the main objections are the damage caused to the crop by heavy equipment and the difficulties of hauling considerable quantities of water.

The difficulties of "automatic" spraying of bush and tree crops increases with the height and distance apart of planting. The most efficient coverage is obtained from vertical masts fitted with nozzles of suitable type and spacing; unfortunately this type of equipment is ill suited to many of our existing plantations. The efficiency of coverage of the target varies considerably with the make-up of the target and the direction and velocity of the wind. Under the best conditions it fails to provide a satisfactory control of such pests as fruit-tree red spider and apple sawfly unless enormous volumes of wash are applied. It is adequate for the application of fungicides. It is essential to use a pump of sufficient capacity to suit the land speed of the machine. The full advantages of automatic spraying are only possible *if the crop is grown to suit the machine.*

Brief mention must be made of permanent pipe systems in which the wash is pumped to conveniently placed "take off" valves, a system well suited to permanent crops. The problem of external corrosion of pipes and leakages is now met by fitting the pipes overhead. Frictional losses due to build up of deposits in the pipes is largely overcome by better lay-out and arranging return circuits to the pump house.

It is unfortunate that many of our spraying machines are special units. It is desirable that the basal design be made so that it can be modified without any structural alteration to suit a number of crops. The only modifications should be changes in ancillary equipment.

* Fruit-Spraying Machinery Broad Specifications for Power Machines.—*Agriculture*, 53, pp 203-207. August, 1946

Kearns, H G. H, Hydraulic Spraying Machinery for Fruit Crops. The Choice of Power Equipment *Rep agric hort Res Sta Bristol 1945*, pp. 110-132 [1946].

Air-Flow Equipment

This group includes (*a*) dusters of many types, (*b*) machines applying the normal type of washes injected at low pressure into large volumes of low-pressure air, and (*c*) machines that apply small volumes of highly concentrated materials into large air volumes of 5 in. W.G. pressure and greater.

Hand dusters, which are used throughout the world, are still of poor design. The rotary type in which the dust is fed on to the fan blades provides the best performance, and better designs are likely to be on the market in the near future. Power dusters using the same principle of operation are gradually being developed, and a tractor trailer machine with an adjustable high clearance axle fitted with a paddle fan delivering about 2,000 cu. ft. of air per minute at 1—4 in. W.G. pressure is likely to become a popular type. Open port delivery of the dust avoids all the complications of multiple spouts and provides equally good results. The use of higher pressure offers little advantage, unless it is used with large air volumes. In many instances, a dusting machine is a convenient means of discharging a calibrated amount of dust into a wind of low velocity, the wind depositing the dust, or at least a portion of it, on the target area.

In the United States and to a limited extent in this country, large spraying machines have been developed for fruit crops in which the normal types of wash are injected at a pressure of about 80—100 lb. per sq. in. into a large air stream produced by a single-stage propellor-type fan; the air carries the droplets into the trees. The air replaces the kinetic energy that would be acquired by the droplets if discharged at high pressure. It seems doubtful if this type of machine can offer any great advantage in performance over a high-pressure pump or pumps using the same horse-power.

Fan equipment is now under development in this country and the United States in which large air volumes are discharged at 5—10 in. W.G. pressure and small droplets of highly concentrated materials are injected into the air stream. Preliminary experiments have shown that this technique of application is likely to have many uses, once the technical difficulties of building high speed multi-stage axial flow fans have been overcome. It is hoped that a British built experimental machine will be available before long for experimental work in this country and for locust control by Dr. Gunn. This type of equipment is likely to be expensive, owing to the fan design and the nature of the ancillary equipment. It would be unwise to suggest that this new development is likely to be the answer to all application problems. For many years, if not indefinitely, hydraulic pressure equipment will play a big part in pest and disease control.

In conclusion I would express the hope that applied entomologists and mycologists will become more mechanically minded and specify their requirements for equipment more exactly.

Dr. Berkeley: The trend to-day in Canada and the United States in so far as spray equipment is concerned is to reduce the weight of machines, to use concentrates and still further reduce the weight when loaded, to replace man-operated guns and brooms by mechanical spraying, and to speed up spraying operations generally. All these efforts, if successful, would cut down appreciably on costs of spraying and release labour for other operations and, in addition, would assist materially in overcoming the difficulty of inadequate supply of water on many farms.

Several machines now on the market, though still more or less in the experimental stage, give promise of meeting these trends. Most of these machines are lighter in weight, use concentrated spray materials (about one-tenth of the amount of water in comparison with conventional sprayers for the same acreage),

eliminate the spray gun or broom, cut down on labour overhead appreciably, and reduce considerably the time required for spraying. But all models to date have one or more weak points that must be corrected if they are to come into general use. These new machines can be placed in at least four categories.

(1) The liquid-duster, which uses dust that is wetted as it comes from the air blast outlet; the latter is circular in some machines and fish-tail in shape in others.

(2) The so-called mist or fog machines, in which concentrated spray solutions or suspensions are atomised by steam hydraulic pressure or air blast. Most of these machines have fish-tail outlets.

(3) The mist sprayer-duster, which has a duster attachment so that it can be used as a mist sprayer or mist duster.

(4) The type represented by the speed sprayer, which passes dilute or concentrated sprays under low pressure through fixed nozzles, the spray being carried to the trees by air blast.

The Buffalo Turbine, Bean Mist Sprayer, and other machines of this type use air blast to atomise and project the spray, whereas the Tifa and Besler generate fog by heat in a combustion chamber at 600 to 900° F. In the Tifa, for instance, the liquid and dissolved or suspended materials are pumped under low pressure from a separate container to the combustion head, and flow out in a thin film around the heated head, being transformed by heat into a very fine fog. The fog is carried by air current to the trees. Power is supplied by an air-cooled gasoline engine. Weight of the machine empty is about 700 lb In tests with the Tifa at Simcoe, Ontario, it was found that the common fungicides and insecticides tested were readily dispersed at concentrations having only one-tenth the amount of carrier used in conventional machines The weakness of this machine was its inability to make good coverage against wind velocities of ten or more miles an hour. Certain results at Simcoe also suggest the possibility that the high temperature used in fogging may act detrimentally on some spray materials, in this case DDT. Another weakness observed with the fog type of machine was the uneven distribution of spray materials, even when spraying was done at night under comparatively calm conditions. Nevertheless, with certain improvements in construction, this type of machine has promise, especially if a forceful air blast is provided

The Buffalo Turbine sprayer-duster, Bean Mist sprayer, Bean Mist sprayer-duster and Bean Rotomist applicator are examples of the new trend in direct air blast machines The spray under low pressure is ejected into the air blast at the top of the air-blast outlet, so that the spray is broken up into fine particles and carried to the trees by the air blast. The direction of the air blast in the "Mist sprayer" is at right angles to the machine, while in the Buffalo Turbine it is directed backwards at about a 45° level Tests to date indicate that the right-angle delivery is preferable One of these machines can spray an acre from one side in about 30 minutes.

The Bean Mist sprayer when empty weighs 2,400 lb. and has a wind velocity of 120 miles an hour This machine seems to be of unnecessarily heavy construction. Also it is higher than is desirable. The Buffalo Turbine weighs about 900 lb when empty and has a wind velocity of about 200 miles an hour. Both these machines need improvements to reduce the particle size to about 30—50 microns The spray droplets in machines used last year were too large. The Bean Rotomist concentrate applicator pre-atomises concentrates in an air stream of 165 miles an hour with a powerful auxiliary blower. This controlled mist is then projected into the main air stream, where it can be mixed with dust or

Air-Flow Equipment

This group includes (*a*) dusters of many types, (*b*) machines applying the normal type of washes injected at low pressure into large volumes of low-pressure air, and (*c*) machines that apply small volumes of highly concentrated materials into large air volumes of 5 in. W.G. pressure and greater.

Hand dusters, which are used throughout the world, are still of poor design. The rotary type in which the dust is fed on to the fan blades provides the best performance, and better designs are likely to be on the market in the near future. Power dusters using the same principle of operation are gradually being developed, and a tractor trailer machine with an adjustable high clearance axle fitted with a paddle fan delivering about 2,000 cu. ft. of air per minute at 1—4 in. W.G. pressure is likely to become a popular type. Open port delivery of the dust avoids all the complications of multiple spouts and provides equally good results. The use of higher pressure offers little advantage, unless it is used with large air volumes. In many instances, a dusting machine is a convenient means of discharging a calibrated amount of dust into a wind of low velocity, the wind depositing the dust, or at least a portion of it, on the target area.

In the United States and to a limited extent in this country, large spraying machines have been developed for fruit crops in which the normal types of wash are injected at a pressure of about 80—100 lb. per sq. in. into a large air stream produced by a single-stage propellor-type fan; the air carries the droplets into the trees. The air replaces the kinetic energy that would be acquired by the droplets if discharged at high pressure. It seems doubtful if this type of machine can offer any great advantage in performance over a high-pressure pump or pumps using the same horse-power.

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discharged alone at a velocity of 90 miles an hour. The object of this pre-atomisation is to avoid the use of an excessive air blast, 150—165 miles an hour, in carrying the mist to the trees. This machine weighs 2,200 lb.

Before some of the concentrations used last year are cited, it should be pointed out that the matter of concentrates is still in the experimental stage, even more so than these new-type machines themselves. Spraying with concentrates is so new that general recommendations are not yet possible. Sufficient tests have been made to indicate that certain concentrates can be applied with safety, but the percentage of concentrate has yet to be worked out for all materials. The following examples will suffice to give an idea as to the concentrations used so far in tests in the United States and Canada. In Washington, these have been 25 lb. 50 per cent. wettable DDT to 12½ gals. water per acre; 40 gals. lime-sulphur and 20 gals. oil to 60 gals. water per acre; and 24 lb. of 50 per cent. DDT plus 1 gal. spreadrite to 115 gals. water per acre. In British Columbia, 16 lb. 50 per cent. DDT in 50 gals. water per acre (Bean Mist sprayer) gave most satisfactory control of codling moth; the cost for 10-acre block for fuel, including tractor, and labour was $15.00 in comparison with cost of $55.00 for conventional tractor drawn unit. In Ontario, both fungicides and insecticides were applied at the strengths used in conventional spraying but with one-tenth the amount of water with good control of scab (Tifa machine) In New York, 25 per cent. oil emulsions applied by mist spray gave deposits of 1·95 mg. oil per sq. inch of surface, while 4 per cent. oil emulsion applied by spray gun gave 2·08 mg.

The deposit of sulphur on peach trees after spraying with lime-sulphur with a mist sprayer with concentration of 26 gals. lime-sulphur per 100 gals. was the same as for conventional spraying with gun with 6½ gals. per 100 gals. In control of cherry leaf spot by the use of copper A, the percentage of leaves infected was 9 for a spray-duster, 3·7 for mist sprayer and 3·5 for conventional sprayer. In apple-scab control with a micronised wettable sulphur, the percentages of scab on the fruit were 3·9 for a spray-duster, 3·07 for a mist sprayer, 2·64 for a conventional sprayer, and 35·9 for no treatment. These are sufficient examples to indicate the following trends.

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There is another type of spray machine, the new speed sprayer. This is extremely heavy, weighing 5,000 lb., and costs about $4,000 so that it is suitable for the larger operators only. Spraying is purely mechanical and up to five acres can be covered in an hour. Originally the speed sprayer was designed for conventional dilute spraying and was intended purely to save time and labour. But by changing the nozzles to a low-volume type, the speed sprayer becomes an efficient concentrate machine. Some owners claim treatment of 15 acres per hour when it is used as a concentrate machine. As little as 25—40 gals concentrate can be applied per acre.

This machine has a bank of 150 stationary nozzles with a centrifugal pump of a capacity of 250 gals. per minute. The air blast in the earlier machines was obtained by an aeroplane propeller behind the nozzles, but more recent models employ rotary-type fans. The machine is powered by a 110 H.P. gasoline engine. It can deliver 950—1,750 gals. per hour and requires only one operator on the tractor so that it is a great saver of time and labour. Several of these machines are in use in Ontario and are well thought of by their owners.

In the United States, and to a less extent in Canada, various types of booms are now in use on conventional high-pressure machines in an effort to overcome the human factor in spraying and to cut down costs. These are of various types and shapes, but all consist of a series of nozzles or guns along a vertical or curved mast or tower, and so make spraying a mechanical proposition and do away with hand-operated guns or booms. There are several on the market, and many growers have made their own to meet their special requirements. These booms are not fool-proof and considerable attention must be given to them when in operation to change the direction of spray when small trees are interspersed with large ones, etc. However, many of them appear to have given satisfaction. In Maine at the experiment station (Highmoor Farm), two booms, called the Highmoor multiple boom, with 16 nozzles, and the Highmoor sectional boom, with 14 nozzles, have given good results. It is stated that experimental tests have indicated a saving of 45 per cent. in time required for spraying, 30 per cent. in gallonage used and 73 per cent. in man-hours of labour in applying the sprays. These booms are attached to the conventional high-pressure machines, though they require a pump with a capacity of 20 gals. or more per minute for satisfactory operation.

There is a very interesting development in the prairie provinces in connection with spray machinery for applying 2,4-D to kill weeds in grain fields. In addition to the use of air-blast machines, which have proved fairly satisfactory, the investigators there (Knowles and Armstrong) have found that the use of certain types of low-volume spray nozzles on the cheap conventional boom sprayers enables good results to be secured with pressures as low as 40—50 lb. When such machines are equipped with suitable nozzles, as little as 5½ gals. concentrated 2,4-D (up to 2 lb. pure 2,4-D) can be applied per acre at a speed of five miles an hour with very satisfactory kill of weeds. Such machines cost about $200 in comparison with $1,500—$2,000 for the air-blast type of machine. In other words, the conventional potato-sprayer or similar types of sprayers that apply 60—80 gals. spray per acre, may, by the simple expedient of using low-volume nozzles, be changed to apply as little as 5½ gals. per acre of a concentrated solution of 2,4-D.

Another new development in agricultural machinery is the introduction of the slurry method of seed treatment. In principle it involves the application of disinfectant to the seed in the form of a water suspension or slurry. Each bushel of seed treated receives the same amount of chemical. The advantages of this method are that it eliminates dust, thus protecting the workmen, and provides an even coverage of each seed

In operation, the disinfectant slurry is carried in accurate measuring cups on a small conveyor belt, and the cups dump the disinfectant into a measured quantity of seed. The seed and disinfectant are then mixed by rotating nylon brushes, which avoid any injury to the seed. Adjustments are provided to increase the speed of operation, and to measure the amount of seed. A large conveyor cup is provided for use with large seeds, and a small one for small seeds. As much as 300 bushels of maize have been treated in an hour. Each slurry bucket contains enough disinfectant to treat approximately 10 lb. seed, provided that the proper seed gate and bucket are used.

At the present time two seed-treatment formulations are available in Canada, namely "Arasan" S.F for vegetables and maize and Ceresan M for cereals and flax. Tables have been prepared giving the number of seed gate, the size of slurry buckets and amount of disinfectant for each seed. For instance, string-bean seed requires seed gate No. 15, slurry buckets of 23 cc. capacity and 24 oz. Arasan S.F. per gal. Cabbage seed requires seed gate No 5, slurry buckets of 46 cc. capacity and 24 oz Arasan S F. per gal

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The slurry treatment increases the moisture content of seeds by not more than 0·5 per cent. Actually the seeds dry so quickly that they can be bagged and stored shortly after treatment, or sown at once.

The CHAIRMAN said that Dr. Kearns apparently envisaged development in Great Britain as improvements in old-fashioned types of machinery for the next few years, whereas Dr. Berkeley expected almost complete revolution in spraying methods in Canada and the United States. He wondered how far the difference, if it was real, was due to climatic conditions. In Britain, the weather was unreliable, and high winds were frequent, whereas it was reasonably fine in the other places.

Dr. KEARNS considered that his own outlook was cautious. If low volumes of spray were used, the droplets would be small (20—100 microns) and difficult to place on the target. In Britain, absence of wind was rare, and a wind of four miles an hour or more led to difficulty with small droplets. Small droplets would probably become very valuable on ground crops, but doubtfully so on trees.

Mr. W. A. ROSS stated that in Canada it was thought that, within ten years, directed aerosols or mist sprays would be largely used in orchards. Dr. Marshall of British Columbia had developed a promising directed aerosol and mist sprayer, with atomisation by steam or a hydraulic unit, and velocity and direction controlled by a turbine blower. Dr. Marshall thought that, in this machine, the optimum concentration was one-tenth of the normal amount of water, and that results were promising and old cover sprays probably obsolete. The speaker did not know. With this machine it was possible to spray under any conditions possible for conventional sprayers. The advantage was the saving of water.

Discussion: **Application of Insecticides from the Air**

The CHAIRMAN called on Dr. D. L. Gunn to open the discussion.

Dr. GUNN: The use of insecticides is not the ideal method of controlling insect pests, but is essential in some cases until appropriate better methods are developed. Aircraft are being widely tested for distributing insecticides. As with other comparatively new things, there is a good deal of careless talk about the various aircraft methods, some people exaggerating their potentialities and others dismissing them rather lightly. In fact, of course, there are things that can be done with them and there are other things that are too costly or perhaps cannot be done at all. What, then, are the principal limitations of aircraft methods and what seem to be their best uses? The Anti-Locust Research Centre has sponsored three sets of field trials of the use of aircraft against locusts, in 1944, 1945 and 1947, and I have been involved in the last two. My experience is thus limited to attacks on locusts; that leaves plenty of scope for members of the audience during the discussion.

Let us consider the matter in this order: first how to get a sufficiently homogeneous *coverage* for the particular insects in question and how to aim that material from the air; then the obstacles in the way of hitting the target, or *shielding*; then the *assessment* of intensity of deposit of the insecticide; and last, some of the factors affecting *costs* and the consequent promise of useful *applications*.

Coverage

Getting an adequate cover of insecticide on the target area obviously depends on how much you are prepared to use. Modern synthetic insecticides are so powerful that they can be effective at astonishingly low dosages. For example, under ideal conditions about 1 oz. of pure DDT spread over an acre of water will kill all the mosquito larvae in it, while 4 oz. of DNOC (dinitro-ortho-cresol) also under ideal conditions, would kill all the locusts basking on an acre of flat ground. The difficulty is, of course, to get the insecticide spread out properly. More than these amounts must be used in practical operations, but it is necessary to keep the dosage as low as possible because of the cost of using aircraft—the lower the dosage, the smaller the flying costs. So I am going to postulate an area dosage several times as great as the ideal, with a solvent or diluent to help in getting homogeneity, making altogether about 1 gal. or 10 lb. per acre. This dosage is practical for locusts, excessive for mosquito larvae, and probably too low in some other cases.

Under the heading of coverage we consider (*a*) *grain* (granularity or pattern) and (*b*) *patchiness and aiming*. By grain I mean the size and frequency of the droplets or particles of dust in relation to the size of the insect; patchiness arises because, for example, the insecticide is laid in lines between which there may be imperfectly covered patches.

Grain

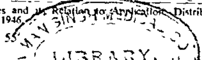
It has been calculated* that application of 1 U.S. gal. per acre in droplets of a diameter of 0·1 mm., 10 μ and 1 μ gives 1·78, 1·78 thousand and 1·78 million droplets per sq. mm., respectively, while application in droplets of a diameter of 1 mm. gives 1·1 droplets per sq. in. Suppose you are spraying insects on a hypothetical plane surface. A locust has a target area of about a square inch, so drops of 1 mm. diameter would not be hopelessly large. They would in fact be too large, because in a random scatter some locusts would get two or more drops and some would get none; but 5—10 drops per square inch would be adequate, so drop sizes between 0·1 and 1 mm. would be all right. Similarly for mosquito larvae, the largest of these drops would do, because the targets are not the individual insects but water surfaces on which the insecticide can be made to spread. With insects having a target area of only a square millimetre, on the other hand, drops of 0·1 mm. diameter are too big. Further with smaller insects on crops, we are not dealing with a plane surface, but with leaf and stem surfaces many times as extensive. Consequently the number of drops adequate for an acre of ground may be far too small for the foliage on that acre. To get coverage for small insects on foliage, then, you have to use a fine spray or dust, under 100 μ.

Patchiness and Aiming

Having decided on the required size of bullets, it is necessary to consider how to aim them

Porton method.—If you simply pour a liquid out of an ordinary aircraft, the liquid is immediately shattered into drops by the rush of air. The sizes of the drops are varied in any case and the size range depends on the speed of the aircraft and the viscosity of the liquid. Under standard conditions you can get a repeatable range of sizes or drop spectrum. Those drops fall at terminal velocities which depend on their sizes; they form a sheet, with big drops below and small above, drifting on the wind; the big ones reach the ground first, and the small ones later If the aircraft flies across the wind while spraying, the result is that a wide band of ground is sprayed, the big drops forming the up-wind edge of the band and the smaller drops the down-wind edge. By

* Potts, S. F., Particle Size of Insecticides and its Relation to Application, Distribution, and Deposit—*J. econ. Ent.*, 39, pp. 716—720. 1946.



knowing the drop spectrum of the insecticide, measuring the wind speed and adjusting the height of the aircraft inversely, the spray can be aimed reasonably well.

By this technique, we sprayed locusts last October with swathe spacings of usually 88 yards but up to 200 yards and got practically 100 per cent. kill. This was possible because locusts are big, so that big drops can be used, and they can be aimed from several hundred feet. But we virtually ignored drops below 0·1 mm. in diameter (100 μ) because they take so long to reach the ground that they drift very far, and they probably evaporate a great deal, too, in their fall. But it is drops smaller than 100 μ that are required for getting good coverage for small insects. So the Porton method is not readily applicable in such cases. When it is used, the liquid has to be chosen not only so as to give the appropriate toxicity, but also to give the appropriate drop spectrum and to evaporate as little as possible while falling to the ground.

Cloud method.—The Porton method has been designed scientifically and can be used and checked by fairly accurate methods. The cloud method, on the other hand, has a very limited fundamental basis, but is the method most commonly used. Since small drops and dusts cannot be aimed from any height, they have to be released very near the ground. Air that is heavily charged with dust or fine spray is virtually denser than the surrounding air and tends to fall massively; if the material is pushed out under the wings of the aircraft, it also tends to be pushed down. This applies both to fixed-wing aircraft and to helicopters. So the fall of a fine spray or dust, which would otherwise be very slow, can be assisted somewhat. Nevertheless, to get it down on to the desired area, we have to apply it from tree-top or crop-top height. The result is that we cannot get a wide swathe, but are usually limited to something like 15 yards. In doing this, some 5—10 times as many runs are necessary as with the Porton method, so the flying time to be paid for is much greater. In addition, some sort of mechanism is needed for making fine drops and for spreading the droplets or dust out laterally as far as possible; the weight of such mechanism reduces the payload of the aircraft.

This is the usual method of crop spraying or dusting. It is also substantially the method by which the South Africans are attacking tsetse with smoke, which is really a fine spray made by the heat in the engine exhaust pipes. They have also for years been dusting wattle for wattle bagworm in this way. A great deal of investigation is required on the effects of the dispersal mechanism and the formulation of the insecticide on the coverage obtained by this method.

Curtain spraying.—This is an application of the Porton method of attack to flying swarms of locusts. At present it is of interest only in connection with locust swarms, so I will not enlarge on it here. An account of it is in the press.

Neither the Porton nor the cloud method can conceivably give a deposit free from patchiness, even in ideal conditions of wind and machinery. Patchiness of some kind is inevitable. The question is how to get at least a lethal dose everywhere, and to expend as little as possible above this.

With the Porton method, the densest contamination occurs near the up-wind edge of the swathe. It is then necessary to overlap deposits, which can produce a fluctuating but always adequate deposit. Other things being equal, the further apart the aircraft runs, the greater the peakiness, but the less the flying time to be paid for. Peakiness can be reduced by increasing flying height, but losses by evaporation and by various errors then increase, so a compromise must be reached. In any case, the ideal dosage has to be increased to allow for this sort of patchiness, and also to allow for losses.

The cloud method of aiming has been less scientifically studied. To some extent you can watch the cloud come down and estimate where to lay the next strip. But visual estimation is unreliable—you can often see fine dust or smoke

drifting for hundreds of yards; it looks good, but if it is drifting so far it is evidently not depositing much. Perhaps the simplest and commonest practice is to fly along the wind, not across it, and lay the strips as close as is found necessary by empirical means. There is necessarily considerable waste from drift. Such assessments as I have seen show the deposit in these cases to be very peaky and irregular.

Shifts of wind and changes in wind speed produce patchiness in the best regulated operation. If the ground is heated much, you get rising currents of air that may take fine dust or spray right up and away. For this reason, aircraft dusting or spraying is best done in the cool of the morning or evening, and may be impossibly wasteful and also dangerous in the heat of the day. Even under the best conditions, it is advisable to increase the expenditure of poison to make some allowance for irregularities of wind, flying errors, and the like.

Shielding

It is quite evident that a rain of spray falling on top of leafy vegetation will cover the outside leaves first and perhaps not penetrate to the underneath leaves. For penetrating foliage, there seem to be advantages in using a very fine spray or dust. Even then, however, there is necessarily some deposit on the more exposed surfaces, so there must be a filtration effect, with less material available for the inner surfaces. Some increase in dosage is necessary to compensate for this, if a certain minimum cover is required on all surfaces. Shielding is a very serious matter, in anti-malaria work, the water surfaces are often covered over by dense bush, in anti-locust work, the locusts themselves are often dense enough to shield each other, and when you are dealing with dense crops, the crop itself acts as a filter Investigation is required on the effects of shielding and how to overcome them

Assessment

The Porton method of spraying has been arrived at by a combination of taking thought and making field and laboratory tests. Field tests include the assessment of the density at which the liquid actually reaches the ground over a wide area. Assessments of that kind cannot properly be made by visual inspection and do require precise chemical or physical methods. Even an experienced man may visually estimate a deposit at five times higher than it is. Therefore, when dealing with a situation that is in any way new, precise assessments are essential. This is particularly true for cloud methods, where there is as yet little foundation of general principles on which to base details of technique, and especially important when shielding is in question.

Costs

If the cost of aircraft spraying depended only on the capital cost of the aircraft and of petrol and oil, there would be a boom in the method. I understand from Mr W. A. Baker, of the United States Department of Agriculture, that commercial operators in the States charge 3—6 cents per lb. per acre for the flying only. This is roughly equivalent to between 1*s*. 6*d* and 3*s*. per acre for a dosage of 1 gallon or 10 lb. To this must be added the cost of the insecticide, which will be considerably greater, but must be found if insecticide is to be applied at all. Dr Rene du Toit tells me that Onderstepoort and the S.A. Air Force are smoking large areas against tsetse at an overall cost, including ground transport etc., of 1*s*. 3*d*. per acre, plus 2*s* 6*d*. for DDT solution, making a total of 3*s*. 9*d*. per acre.

To get the charges as low as this, the aircraft and the aircrews and ground crews must be constantly employed; this means that a large area needs to be dealt with in a short time in one neighbourhood.

Possible Applications

It seems unlikely that Porton methods will have a wide application in this country, because the usual target is a crop with insects in it, which requires cloud spraying. Because of the hedges and trees, it seems likely that helicopters may be useful. They are expensive to buy, compared with fixed-wing aircraft, and are inherently expensive to maintain, because of the complexity of the rotating wing. Since there are many crops here that will stand a dusting or spraying charge of £2—£4 per acre, their use may still be profitable. They have the advantage over existing types of ground machine of not damaging the crop by driving through it. Small fixed-wing aircraft are under the disadvantage of requiring airfields, and they seem to be more dangerous to fly at crop height.

Where similar conditions obtain in other parts of the world, helicopters may become equally valuable. But whenever Porton spraying can be used instead of cloud methods, the heavier fixed-wing aircraft will gain in the load it can carry, the distance it can fly, the speed with which it can cover the area, and the price at which it can operate. I am surprised that anti-malaria spraying round certain towns is not done by such aircraft. Whenever the target insect need not be hit directly, but can be left to walk into a residual spray, or to eat the outer foliage after it has been spotted with a stomach poison, Porton methods may be applicable. And they are applicable with large insects like locusts. It would be interesting to hear the views of the audience on possible applications.

Although I have said that Porton methods can sometimes be used against locusts, that does not mean that they are necessarily the best or the cheapest, especially for small areas. Dr. Kearns is, in fact, designing a ground machine (Airflow) that is intended to take advantage of the best features of both aircraft spraying and ground spraying. A great deal of publicity attaches to aircraft spraying, but comparatively little is known about how it can establish itself in competition with other methods, and much more investigation and field work are needed.

The Chairman thought helicopters were likely to become useful in Great Britain, whereas fixed-wing aircraft would probably revolutionise spraying in many parts of the tropics.

Mr. F. N. Ratcliffe asked what quantities of spray were recovered from aeroplane spraying by the Porton method. The best recovery he had obtained with cloud spraying was 50 per cent., but it subsequently appeared that droplets too small to recover were being useful. The spray controlled adult Anophelines sheltering in jungle vegetation when the aeroplane flew at a height of 100 ft. and sprayed 100-yard swathes. The mosquitos were destroyed, although it appeared that most or all of the droplet spectrum that could be recovered was wasted, because it was stopped by the vegetation before it reached their resting places. The small drifting drops must have reached them, possibly because the spraying was done in the early morning, when inversion of air currents carried them down.

Dr. Gunn said that he had obtained 70 per cent. recovery with a liquid designed for Porton application. Spraying at Kisumu had resulted in a quick reduction of Anopheline larvae and pupae in pools, and also an immediate reduction of adult Anophelines, which had not been expected. This was probably due to droplets that were thought to be wasted. A fine spray or dust (or a smoke such as that used against the tsetse fly in Natal) was best applied in the early morning, because temperature inversion was important in getting it down.

Mr. RATCLIFFE stressed the importance of ground reconnaissance and marking, and a proper understanding by the pilot of the target area.

Dr. GUNN agreed.

Dr. J. G. DAVIES cited an observation in Louisiana to show the extent to which droplets can drift. Rice-fields were being treated for weed control with 2,4-D applied at the rate of 1 lb. in 5 U.S. gals. spray per acre from light aircraft with a boom under the wings, and cotton, which was highly susceptible, was destroyed up to ten miles away from the place of spraying.

Dr. R. A. E. GALLEY said that Canada relied entirely on the Porton method with a 4-inch pipe and oils of the right viscosity. The United States used nozzles and booms and low flying, and very good pilots were required for the method to be safe. Applications of weed killers by the Tennessee Valley Authority resulted in damage to cotton crops at a distance under unfavourable conditions. When he had asked workers in the United States what was the actual amount of insecticide applied on the water when DDT was used as a mosquito larvicide, he had been told that the normal method of assessment with microscope slides had been found to be hopelessly inaccurate, as variance was 300—400 per cent. They released 1 U.S. quart solution per acre from the aircraft, but they had no knowledge of the amount on the water. In work in which over 130,000 acres were treated against the gypsy moth, the use of a large Dakota carrying 900 U.S. gals. solution reduced the cost of applying 1 U.S. gal. per acre to one dollar per acre.

Dr. Hem Singh PRUTHI inquired what were the relative merits of baits and aircraft spraying in locust control.

Dr. GUNN replied that they were used in different circumstances. Baits were used almost entirely against nymphs and aircraft almost entirely against adults, because baits were often too difficult to apply against the latter. No comparison was possible at present

Dr. T. SWARBRICK reported that a helicopter had been operated since the second week in April in Holland. Approximately 90 per cent. of the material was now being recovered, whereas only 20 per cent. had been recovered at first. The spray was applied in long narrow strips and was supposed to cover 60 ft., but it actually spread much wider, so that when a whole field was sprayed about 90 per cent. could be recovered. When the spray was applied from 12 ft. above ground, a droplet size of 80—100 µ was satisfactory. With a smaller size there was much loss.

Dr. GUNN was interested in the 90 per cent recovery. He had been told that he got small recovery because he used too few plates.

Dr. SWARBRICK said that the plates were first put on 3-ft. posts and recovery was poor. Later plates round the bottom of the posts were added and recovery was much higher on the ground, though he did not know why.

Dr. K. B. LAL asked whether smoke or spray was better from an aeroplane and what was the difference in cost.

Dr. GUNN said it was necessary to adapt the technique to the particular case. The coarse drops of a Porton spray did not penetrate through forest cover, and there smoke or fine droplets could be tried. On open country, coarse droplets should be used because they were cheap and easy

MEETING: *Monday, 26th July, 2.30 p.m.*

Chairman: Dr. A. J. Nicholson

Discussion: **Biological Control**

The CHAIRMAN regretted that Dr. W. R. Thompson, who was to have opened the discussion on the biological control of insects, had been prevented from attending the Conference. In his absence and at short notice, three other Delegates, Mr. A. B. Baird, Dr. W. Cottier and Dr. R. H. Le Pelley, had consented to read short papers.

Mr. BAIRD: Since Dr. W. R. Thompson was to have opened this discussion, you may be interested in a very brief statement regarding his organisation. Its early history is contained in the reports of previous conferences. In 1940, due to war conditions, the Council of the Imperial Agricultural Bureaux found it necessary to discontinue work at Farnham House, and, after negotiations with the Canadian Government, operations were transferred to Canada, where accommodation and essential services were provided free of charge at the Dominion Parasite Laboratory, Belleville, Ontario. The work was reorganised as the Imperial Parasite Service. Mr. F. J. Simmonds and Dr. C. Lloyd, Scientific Assistants, and Mr R C. Jeffery, Dr. Thompson's secretary, were transferred with him to Belleville. Mr. Jeffery subsequently resigned owing to illness. A number of projects were carried out with the aid of Canadian assistants, and much progress was made on the Parasite Catalogue, nine volumes of which have now been completed and distributed. At the Imperial Agricultural Bureaux Conference of 1946 held in London, the organisation was reconstituted as the Imperial Bureau of Biological Control, and as from 1st January, 1948, it became the Commonwealth Bureau of Biological Control. Staff additions have been made from time to time, and at present the organisation is as follows.

Headquarters: Belleville, Ontario:

W. R. Thompson, Director; G. C. Ullyett, Scientific Assistant; Secretary; Accountant; two Library Assistants working on Parasite Catalogue; two full-time Laboratory Assistants; special Assistants for projects.

Sub-stations:

Riverside, California. W. F. Sellers; Assistants as required.
Montevideo, Uruguay: D. C. Lloyd.
Trinidad: F. J. Simmonds.
Zurich, Switzerland: L. Mesnil (of France) specialist on parasitic Diptera.
Bermuda: at present directed from Belleville.

The work in South America and in Europe is at present very largely on Canadian projects.

Arrangements have recently been completed, following authority of Council, for the transfer of Dr. Thompson's headquarters and library staff to Ottawa on 1st September of this year. He will there have better facilities for continuing the Parasite Catalogue and for developing work throughout the Commonwealth. He plans to maintain the insect laboratory at Belleville for the handling of projects requiring insect-rearing work in Canada—facilities at both places are being provided free of charge, so overhead expenses are not affected.

I have given this review in the hope that all parts of the Commonwealth will contact Dr. Thompson regarding projects in which they are interested, and particularly at present those that can be given service from the laboratory centres

now established. The men at these centres are all well trained and experts in methods of obtaining and shipping parasite material, and can be expected to give the very best service possible. I will be glad to answer any questions I can, or to convey messages to Dr. Thompson on my return to Canada next week.

Referring now briefly to Canadian work. Important progress has been made since the last Conference. The Dominion Parasite Laboratory, established at Belleville in 1929, has continued to grow. In 1935, a project was in progress with Farnham House co-operation, involving the introduction of parasites to aid in control of the spruce sawfly, then known to us as *Diprion polytomum* but later correctly identified as *Gilpinia hercyniae*. This insect was devastating Canadian spruce forests in a manner not hitherto experienced, and the search for parasites extended through central and northern Europe and parts of the Orient as well. To implement this programme of parasite introduction, special quarantine insectaries were constructed at Belleville between 1935 and 1938. These comprise 30 insectary rooms of various sizes and shapes, all with air-tight seal and completely air-conditioned as to temperature and humidity, so that insects from any part of the world can be handled safely and effectively at any time of the year. Quarantine dressing rooms, cold storage and other service rooms are also provided. These facilities supplement the usual administration and general laboratory equipment required in the conduct of such work. This year the work was extended and reorganised with headquarters for Biological Control now in Ottawa. The Belleville laboratory remains as the centre for introduction of control agents and for basic research. It has a staff of more than 50 plus 50—75 students. A regional laboratory for work in British Columbia at Vancouver and one for work in Quebec at Quebec City have also been established, and closer co-operation with workers in other fields is thus being developed and extended.

All studies on insects have demonstrated the important part played by diseases —fungous, bacterial and virus—in their natural control. Up to the present there have been few cases where diseases of insects have been successfully manipulated by man under field conditions. They have, however, been a factor of great importance in large scale propagation of parasites, and the Dominion Parasite Laboratory has for many years been carrying on investigations with disease organisms encountered in the several parasite projects. Important progress has been made in the control of these diseases under laboratory conditions, and their use as control agents under field conditions may be possible. The outbreak of spruce sawfly appears to have been terminated largely by a virus disease of unknown origin; and, as a result of the interest thus created in diseases of forest insects, the Forest Insects Unit of the Division of Entomology has initiated a series of investigations on the causal organisms and has under construction at South Sainte Marie, Ontario, a large and very completely equipped laboratory for fundamental studies that will be of great value in biological control work everywhere.

The more important projects carried out during this period include

(a) Control work of the following pests by introduction and distribution of parasites and predators since 1935.

- *Larch Sawfly (*Pristiphora erichsoni*).
- *Spruce Sawfly (*Gilpinia hercyniae*)
- *Pine Sawflies (*Gilpinia frutetorum*. *Neodiprion sertifer*, *N. similis*, *N. lecontei*, *N. nanulus* and other native species).
- *Larch Casebearer (*Coleophora laricella*).
- Spruce Budworm (*Choristoneura fumiferana*).
- *Pea Moth (*Laspeyresia nigricana*).
- *Greenhouse Whitefly (*Trialeurodes vaporariorum*)
- *Greenhouse Mealybugs (*Pseudococcus* spp.).

* Good results proved.

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*Apple Mealybug (*Phenacoccus aceris*).
†Comstock's Mealybug (*Pseudococcus comstocki*).
†European Wheat-stem Sawfly (*Cephus pygmaeus*).
†Corn Borer (*Pyrausta nubilalis*).
*Oriental Fruit Moth (*Laspeyresia molesta*).
Codling Moth (*Cydia pomonella*).
Grasshoppers (*Melanoplus* spp., *Camnula pellucida* and others).

(*b*) Biological, morphological and taxonomic studies on all parasite species involved in the above projects.

(*c*) Study of disease organisms as related to the various phases of biological control of insects.

(*d*) Basic research studies.

1. Application of the principles of genetics in parasite production. Parasites have been selected for special characteristics, such as high female production, high egg lay, and preference for certain temperature ranges. The use of selected stock has increased laboratory production of some species as much as 20-fold with corresponding reduction in cost of the projects and acceleration of distribution of the species.
2. Investigation of population densities as affecting host-parasite relationships.
3. Environmental factors as affecting parasite establishment and distribution. Acclimatisation of parasites.
4. Alternate and substitute hosts as affecting parasite establishment and distribution.
5. Physiology and nutrition. Use of artificial media in parasite propagation.

Biological Control is not the simple matter it was once thought. Successful work with a great many projects has been carried out but is very complicated and requires continuous study. In Canada at least we can never consider a control project completed; changing conditions create new problems. This is exemplified by the larch sawfly, control of which was our first project initiated by Hewitt in 1909. The parasite, *Mesoleius tenthredinis* (now *aulicus*), gave control wherever it was established, first in Manitoba and Quebec, and then in British Columbia, the Maritimes, Ontario and Newfoundland in turn. Now, however, an infestation is flaring up in Manitoba. Parasitism has been very low for two or three years and examinations have shown that a large percentage of the eggs laid fail to hatch. Why? We do not know, but if it persists we may have an outbreak of destructive proportions. We are making a special study of this at present in co-operation with the forest entomologists of our service.

Another very serious complicating factor in biological control programmes is the use of insecticides and fungicides and this is becoming annually more acute. Such insects as woolly aphis, mealybugs, oriental fruit moth and even the Colorado potato beetle, which are satisfactorily controlled by natural enemies in most years, become much more difficult and expensive to control when these are reduced or eliminated by the use of chemicals. Fortunately this has been realised by most economic entomologists and pathologists, and it may prove possible to develop more selective materials or by proper timing of application to improve control by destroying a large percentage of the pest without injury to the beneficial species.

Another matter of great importance in biological control is the correct identification of species, both host and parasite. In our work on spruce sawfly, much valuable time was lost on account of failure to recognise the presence of two species

* Good results proved. † Good progress.

in Europe, whereas only one occurs in Canada. Some parasites are very specific, and in this case the biology of the two hosts was quite different. On the other hand, when considering introduction of parasites of the pea moth to Canada the parasite *Ascogaster quadridentata* was at first eliminated because it was considered taxonomically the same as *Ascogaster carpocapsae;* the latter was already present in America and being propagated and distributed in large numbers in Canada. However, when laboratory and field tests failed to secure establishment of *A. carpocapsae* on pea moth in British Columbia, the European *Ascogaster* from pea moth was introduced and in five years had increased to the point where upwards of 75 per cent. of pea moth larvae were parasitised in the large area under study. Many similar instances are known to all who have been engaged in biological control work.

To sum up these few remarks, we need in Biological Control:

1. More trained research workers carrying on the fundamental or basic studies essential to continued and extended successful work.
2. Close co-operation at all times with entomologists and pathologists engaged in economic fields of work.
3. More trained taxonomists closely associated with those carrying on biological studies.
4. Frequent and regular immediate exchange of information on work carried out. This refers particularly to work in progress.

DR. COTTIER: The account I am to give you concerns the introduction of parasites into New Zealand to check the ravages of *Pieris rapae*, which we call the White Butterfly.

First of all, I would like to make it clear that the man responsible for carrying out this work has been Mr. John Muggeridge, until lately on the staff of the Department of Scientific and Industrial Research in New Zealand. My own direct part in it has been comparatively small. In its early days, I was actively associated with Mr. Muggeridge in its prosecution, but since 1937 I have had no hand in it and my part to-day is simply to tell you about the work he organised and carried out.

Pieris rapae appeared in New Zealand for the first time in 1929 in the neighbourhood of Napier, the capital town of Hawkes Bay on the eastern coast of the North Island. By the summer of 1931—32 its numbers had increased enormously and by the end of that season it had spread from the initial point of infestation at Napier to areas 100—120 miles away In this same year, it was reported in the South Island in Timaru; how it reached there is not certain, but we consider it possible that the same ship was responsible for its introduction in the north and in the south We think that it possibly floated ashore on cabbage débris thrown from the galley of a ship in the harbour, or else that it was able to complete its life-cycle under the conditions of cold storage in the ship and the adult butterflies escaped when the food containers were opened. By 1933, the butterflies were to be seen in millions flying over roadsides and pastures, whole white fluttering clouds of them being over every cruciferous crop in Hawkes Bay. The pest soon spread throughout the land; by 1935 the whole of the North Island had been covered and by 1936 it had reached to the bottom of the South Island.

We in New Zealand derive most of our income from the primary industries of farming and the appearance and spread of such a destructive pest of cruciferous crops was a very serious matter. The productive capacity of New Zealand's farm lands is far beyond the requirements of the 1½ million inhabitants and the unconsumed surplus, which is sold mainly on the British market, therefore becomes

the chief source of income. The bulk of the primary products, which include wool, mutton, fat lamb, beef, butter and cheese, are dependent to some extent on the successful growing of cruciferous crops and in so far as the mutton and fat lamb trade is concerned, rape in particular possesses a fattening value which makes it intrinsically superior to other crops that have been used for this purpose.

It was soon obvious that the butterfly had come into our country unhampered by any of its natural enemies from overseas, and it did not take much thought to see that the only way we could hope to reduce its numbers was to attempt to introduce these natural enemies. It was an economic impossibility to attempt the application of any insecticide on such a large scale. Therefore a call for assistance in sending us parasites was made to the Imperial Institute of Entomology as it then was, and the parasite laboratory at Farnham Royal at first sent us out *Apanteles glomeratus*, a Braconid parasite of the caterpillars. The first consignment, comprising some 2,000 cocoons, arrived early in 1932. This was followed by three more sendings in the same year, making a total of 100,000 cocoons for that year. Then in 1933 we received 420,000 more. In making field liberations, the bulk of this material was concentrated near one locality in Hawkes Bay. This locality was selected because here the population of the butterfly had reached enormous numbers. Thus there was no chance of the parasite failing to become established through lack of hosts. The parasites were not all liberated at once; on the contrary, they were so managed as to be spread over a considerable period of time. Liberating them in this manner, it was felt, would ensure that some at least would find their host at a suitable period of development. Extensive field surveys were subsequently made in the places where the bulk of the liberations took place; small recoveries of the parasites were made in the season of liberation and again in the following season, but since then no further recoveries have been made in spite of the fact that large field collections of *P. rapae* were made and reared. So it seemed that this introduction was a failure.

I might say, as a possible explanation of this failure, that a very large proportion of the cocoons of *Apanteles glomeratus* recovered was parasitised by a hyperparasite, *Eupteromalus* sp., which had been in the country prior to the introduction of *Apanteles*. This, however, may not be the whole explanation of the failure as I shall suggest another factor when I return to *Apanteles glomeratus* for a moment before closing.

However the second insect introduced, the Chalcid, *Pteromalus puparum*, a parasite of the pupal form, fared much better. It was first introduced from Farnham Royal in the summer of 1932—33. In the two consignments received there were 509 parasitised pupae and from these almost 11,000 parasites were liberated in the field. As with *Apanteles glomeratus*, a central point in Hawkes Bay was selected at which the largest number of parasites was liberated. From a field survey made towards the end of this season it was found that out of a total of 415 butterfly pupae collected 58 per cent. were parasitised.

In the 1933—34 season further supplies of *Pteromalus puparum* were liberated in the same locality These later liberations, however, could not at this stage materially affect the position, as the parasite was already established and commencing to spread outside the area where the initial liberations were made, and by the end of this season it could be found at points at least 80 miles from the nearest points of liberation In the field surveys made during March of this same season, it was found that 89 per cent. of the 5,396 butterfly pupae collected had been parasitised; at the same time the butterfly population fell to such an extent that comparatively few were seen where in previous seasons there had been myriads. In contrast to this, in other parts of New Zealand the butterfly had been able to multiply unchecked, consequently it was very much in evidence and large areas of crops were being destroyed. For example, field collections

made in the winter of that year in the Manawatu district showed that of 32,450 pupae not one was parasitised The results thus far obtained in places where *P. puparum* was established were so promising that work on laboratory breeding and rearing was undertaken in order to establish it as rapidly as possible throughout the country. To this end, large numbers of caterpillars were collected in the field and confined on cabbages at the Research Area at Palmerston North, and the subsequent pupae were gathered and taken into the laboratory, where they were kept in cool storage. During the winter they were parasitised by *P. puparum* by means of a special technique devised for the purpose. The parasitised pupae were subsequently kept in cool storage until the parasites were required for liberation in the following spring and summer. In the 1934—35 summer season, 800,000 parasites reared in this way were liberated in colonies of approximately 10,000 each at various places throughout the country.

Field collections of butterfly pupae were again made in 1934—35; in all, some 24,000 were taken from the Manawatu, Wellington, Taranaki and Hawkes Bay areas. The percentage parasitised varied from 73 to 100, the mean being 92. The rise in percentage of parasitism during the season in districts where in the previous year it was nil, coupled with a remarkable falling-off in butterfly population density, was surely a good example of the effectiveness of the parasite. In Hawkes Bay during this year, the host had been reduced to such small numbers that pupae were few and far between and difficult to find.

Field collections of pupae were continued until 1937. Generally the percentage of parasitism was maintained at a high level

Now to return to *Apanteles glomeratus*. It is interesting to note that it was subsequently introduced into New Zealand from America, and seems to be doing much better than did the European strain In England, *A. glomeratus* is a very useful parasite of *Pieris rapae* but its main host is *P. brassicae*, and possibly it needs this latter to develop its attack on *P. rapae*. In New Zealand *P. brassicae* is not yet present and this possibly contributed to the failure of the European strain of the parasite with us. In America *P. brassicae* is not present either, but there on the other hand *A. glomeratus* is still a valuable parasite of *P. rapae* So it may not be surprising that the American strain of *A. glomeratus*, which seems to have developed the ability to do without *P brassicae*, has done better with us than has the European strain

In the Dominion to-day we feel that the introduction of *Pteromalus puparum* has been of great importance to us While we still have to spray our cabbages, and the percentage of parasitism fluctuates so that in some areas the butterfly gains the upper hand now and again, the general overall efficiency of the parasite in protecting the cruciferous fodder crops of our cattle and sheep has made its introduction of very great value to New Zealand farming.

Dr. Le Pelley: A paper on the biological control of the common mealybug of Kenya has been circulated, so I will only summarise this project and then mention some points of general interest.

Firstly, I must say that it was a joint piece of work in which my colleague, Mr. Melville, and I were associated.

The mealybug was first noticed in Kenya in 1923, when a severe attack occurred on coffee in the Thika district. From here it spread north and south to cover a part of the central province including important coffee areas and productive native reserves Its severity in the early years can hardly be exaggerated, the trim green rows of coffee bushes too often became a forest of dirty sticks, almost leafless, while whole areas of native crops became black and ruined.

The insect was at first thought to be *Pseudococcus citri*, then *Pseudococcus lilacinus*, an Oriental species, and many attempts at biological control, all unsuccessful, were made. In 1934, however, it was recognised to be distinct from *lilacinus*, and I described it in 1935 under the name *Pseudococcus kenyae*. A search for parasites was then begun in Uganda, Melville doing the collecting, while I was at the receiving end. A large number of shipments of parasitised mealybugs were made and nine species of primary parasites were bred; five of them were put into large-scale production and liberated. All became established, but one rapidly became the dominant parasite. A remarkable diminution of mealybug followed; expensive control measures in coffee were almost entirely abandoned, and in the native reserves the clean-up was so complete that generally the mealybug could only be found with difficulty. Limited increases, here and there, now occur, which, from experience of other cases, is to be expected. In this case, an indigenous injurious hyperparasite is present. On young sucker growth on coffee, the mealybug sometimes increases, and search for additional parasites in Uganda to look after this is planned.

The very favourable result of the introduction has been virtually maintained for nine years, and it can be stated that the parasites have been a remarkable boon to European and native alike.

I should like to mention some of the points of general interest. The insect in Kenya is clearly an introduced species in view of its mode of spread and the fact that it was almost entirely without parasites. On the other hand it has all the signs of being an indigenous species in Uganda, where it maintains a great complex of primary and secondary parasites. The barriers to its spread are physical and ecological, physical like the mountain in Kenya and the lake in Uganda, and ecological such as the acacia-grass zone, which for reasons not fully explained, it does not penetrate. We therefore had a condition on a continent comparable with the better-known cases where a continental pest has been transported to a real island

The crucial importance of taxonomy is evident in this instance, since the probable solution of this biological control problem only became evident when the insect had been correctly placed as an undescribed species.

The known primary parasites of the mealybug comprise one species each of the genera *Leptomastix*, *Coccophagus*, *Tetracnemus*, *Pauridia* and *Pseudaphycus*, and four species of the genus *Anagyrus*. The dominant parasite is a species morphologically indistinguishable from *Anagyrus kivuensis*, but apparently biologically different. It has all the attributes of an efficient parasite; it is vigorous, hardy, adaptable, mates readily and is an excellent searcher. Alone, it can hold the mealybug at a very low population level. This means that it must be able to destroy a greater proportion of the host population when the density of the host population is high than when it is low, otherwise it would not be a regulatory factor.

Another parasite, *Anagyrus beneficians*, breeds very readily in the laboratory, but cannot normally maintain itself on such a low population of mealybug as the other *Anagyrus*, and this must be because it is not such a good searcher. In some conditions, however, it increases markedly and is the chief parasite; this most often occurs in the less altered conditions of the native reserves.

These two parasites of the same genus may be considered to occupy slightly different ecological niches, if this expression is used, not as a synonym for habitat, but in the sense of Elton and refers to what the parasite is doing, its place or rôle in the biotic environment. This can be taken to indicate that there is advantage in introducing more than one parasite, even though one of them is normally dominant.

A word on insecticides. Biological control cannot replace spraying, which will always be necessary in order to control many insects, but biological control, which we have only just begun to exploit, should be more and more used. It will be necessary to reconcile these two methods of insect control. Personally I am not seriously worried about the effect of sprays on parasites, provided that due thought is given to each particular case. We have for a long time used arsenic and pyrethrum sprays on coffee without disturbing the biological control of mealybug. With DDT we may run into more trouble, but the occasional use even of DDT may not prove entirely incompatible with parasitic control.

The case described has proved a very successful case of biological control on a continent, but we have also exported many parasites, and perusal of some of the reviews of work submitted to this conference shows a good many pests for which parasites, likely to be of value, exist in East Africa.

I suggest that a very useful object would be attained by officially sponsored work in the Commonwealth to study the parasites and predators of insects that may not be pests in the country concerned. A wealth of data would thus accrue that could be turned to advantage. The work would be one of reciprocity, each country benefiting not so much from its own work as from the work of others.

Two last points.

(1) We need a permanent biological control station or sub-station in East Africa to exploit the beneficial insect fauna of East and Central Africa.

(2) We need many more workers and much more work on biological control, and for this I suggest that we should have a school in the United Kingdom where, after graduation, students could get specialist training in biological control, and where young entomologists would have the opportunity of becoming interested in this very important practical branch of the applied field.

The CHAIRMAN then called on Dr. D Miller to speak on the biological control of weeds.

Dr. MILLER: When plants are released by some means from one or more of their controlling factors, they can become noxious to man. What all these controlling factors are is by no means sufficiently known: they embrace many biotic influences, some of which, such as diseases and insects, are obvious, and there are also the physical conditions of soils and climates.

The economic needs of civilisation frequently bring about a set of conditions releasing many a plant from its normal restraining influence. This is often apparent where the dominant natural plant cover has been rapidly stripped and replaced by extensive areas of pasture that cannot be maintained owing to sparsity of human population or to unsuitability of climate, soil type, etc.; in such deteriorating pastures, useless plants can enter into competition with the plants that, in a normal succession, would ultimately lead to a regeneration of the natural cover, so that the natural vegetation suffers and a weed problem develops over extensive areas. On the other hand, the position does not arise on arable land that is properly managed and where human populations are denser; but even there, in cases of neglect, the useless plants take charge and become dominant.

Apart from this, the abnormal development of a weed established on a favourable site can be intensified by the absence of controlling diseases and insects; on the other hand, it can happen that, even when such diseases and insects are present, they may have but little influence because physical factors are being less favourable to them than to the weed

However, we are not concerned in this discussion with the whole aspect of the weed problem, but only with the utilisation of phytophagous insects as controlling factors. Mention has been made of plant diseases, but since there has been very little study of them in relation to weed control, and since their behaviour is frequently very complicated, it is extremely doubtful whether there could be sufficient safeguards against infection of valuable plants by diseases that might be used against weeds.

In several aspects, the control of weeds by means of insects parallels the biological control of insect pests; but it is much more restricted in its scope, being involved so deeply in phenomena, largely unknown to us, that govern the powers of host selection by phytophagous insects. In this we are faced with possibilities, over which we have no control, of some of such insects sooner or later extending their host range to plants of economic value. Compared with this, any danger from entomophagous insects is virtually negligible and can be much more readily guarded against; on the other hand, we have now the experience of how incalculably valuable the biological control of a major weed can be without other hosts being attacked—for example, prickly pear and St. John's wort in Australia and gorse and St. John's wort in New Zealand.

A review of the behaviour of some phytophagous insects will reveal certain features having a bearing upon the practice of biological control of weeds. Many insects are polyphagous, many are restricted in their host range to one order of plants, many to one genus, and others even to one species. With the polyphagous species we have no concern for obvious reasons; but all of the others are of interest, especially those confined to a specific host, in that they illustrate some fundamental features.

Of insects that are restricted to a single species of plant, I have in mind the blue-gum chalcid (*Rhicnopeltella eucalypti*), a Tasmanian insect established in New Zealand where it is actually destroying throughout the country, over a period of years, the Tasmanian blue gum (*Eucalyptus globulus*), but does not attack any other species of eucalypt. On the other hand the various species of *Eucalyptus* are attacked by the scale, *Eriococcus coriaceus*, the Chrysomelid beetle, *Paropsis dilatata*, and the weevil, *Gonipterus scutellatus*—all Australian species normal to the hosts. The scale actually kills the trees, especially the more susceptible *Eucalyptus globulus*, but little harm is caused by the beetles except that the weevil may cause a pronounced stunting of growth. These three insects are very common throughout New Zealand but attack no other plant, except that the scale has been found attacking apricot and the weevil apple, though so rarely and so slightly that the habit is really an accidental one—virtually comparable to the case of a cicada that oviposited in the leather of a shoe exposed to the sun.

The European horntail borer, *Sirex noctilio*, thoroughly established in New Zealand, attacks such exotic conifers as *Pinus radiata*, *P. austriaca*, *P. mauritanicus* and *Larix decidua*. On one occasion it was found ovipositing in the New Zealand miro (*Podocarpus ferrugineus*) without infestation resulting; but no other timber trees than the normal exotic conifers mentioned above have become hosts, though the insect is now one of the most abundant in the country.

Though phytophagous insects that are normally confined to one order, genus or species of plant may be occasionally found on other plants, and though it is usual that they do not thus permanently extend their host range, there are occasions when a new host preference permanently develops. This is well illustrated by the blueberry maggot (*Rhagoletis pomonella*) in the United States. In this case the host range extended from blueberry to apple, and an apple race developed, larger than that on the blueberry. Though no morphological changes are apparent in the new race, the timing of the seasonal cycle is slightly different, and all attempts to transfer the two races to their opposite hosts failed.

The case of the blueberry maggot involved a new host within the same botanical order as the original one; but instances occur where the new host is of a different order. For example in England *Plesiocoris rugicollis*, which normally occurs on willow, became a serious pest of apple somewhere between 1900 and 1910; as with the blueberry maggot a variation in the seasonal cycle resulted. According to Imms this Capsid can be artificially transferred from willow to apple and to other hosts such as plum, but under natural conditions it prefers to remain upon the host on which the eggs hatched; it is also recorded that where infested willows had their branches touching and intertwining with those of apple, no transfer took place. I gather that this Capsid has always been a pest of apple in Scandinavia; if this be so, then there is the possibility of there being an English and a Scandinavian race which stimulates the thought that the appearance of the Capsid of apple in England might have been due to the introduction of the Scandinavian form, rather than to a change of host by the English form; under such circumstances, the issue might perhaps be further clouded by the interbreeding of the two.

Also there is Paul Marchal's work on the transfer of *Eulecanium persicae* from peach to false acacia (*Robinia pseudacacia*); the progeny from those that survived on the new host throve thereon, but could not be brought to sexual maturity when transferred to the original host. This leads up to the case of the white scale, *Diaspis pentagona*, recorded by Howard. This scale is a serious pest of mulberry in Italy but infests peach, cherry and other plants in the United States where it did not spread from an infested peach tree to a mulberry tree although their branches interlocked. Finally we can note Pictet's statement that *Lasiocampa quercus* was known on the leaves of oak and of certain shrubs in the time of Linnaeus, but now attacks a number of trees; and that of two varieties of this species, *callunae* in Scotland prefers heather, and *roboris* in England *Quercus robur*.

The foregoing will briefly illustrate that there are possibilities of extension of host range by phytophagous insects normally restricted in their preferences. Although it is the rule rather than the exception for insects with a restricted host range to adhere to that range, the possibilities of some insect permanently extending its food preferences cannot be overlooked; and it is just such possibilities that present a weakness in the utilisation of insects against weeds. The attitude of Imms toward such types of insects is that "They are, however, far too few in number to warrant any general deductions to be drawn therefrom, and it by no means follows that analogous behaviour would necessarily result with a vast number of other insects." With that view one agrees, and there is ample evidence in support of it, but when it comes to the deliberate use of insects against weeds, one realises the need for a deeper knowledge of the many factors influencing insect behaviour.

Nevertheless, though no absolute guarantee can be given of the ultimate behaviour of phytophagous insects, the benefits to be derived from their successful use are of incalculable value, as has been proved, and the danger from their use can be minimised by studying the insects under rigid tests. The general principles to follow in any scheme for the control of weeds by insects are:—

(1) In the case of alien weeds, their insect inhabitants should be sought for and studied in the natural habitat of the weeds, or even in new habitats. If a weed be indigenous, then a search should be made of the insect inhabitants of allied weeds in other countries. From these insects should be selected only those restricted to the order to which the weed belongs where no valuable plants of that order would be endangered; if there should be such plants then only insects specific upon the weed should be considered.

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(2) In the botanical relationships between the weeds in question and plants of economic value, it is assumed that the more isolated a weed is botanically the less danger there should be of the insects restricted to it becoming a menace to other plants. The thought arises, however, that botanical isolation need not necessarily be a barrier in that a botanically unrelated plant could in some way be found palatable to an insect of specific host range; one aspect I have in mind of such a possibility is that a hitherto resistant plant might become palatable as an unexpected outcome of plant breeding.

Besides botanical isolation and unpalatableness as barriers there are others. For example, there are morphological barriers in the case of the gorse seed weevil, *Apion ulicis;* it breeds in the pods of gorse and occasionally of broom, and tests with other legumes, including native New Zealand ones, showed that it was not interested in them, or if so, then the structure of the pods prevented oviposition. Again with sawfly, *Antholcus varinervis*, imported from Chile for use against species of *Acaena* in New Zealand; the sawfly endeavoured to oviposit in the leaves of strawberry, but was prevented from doing so by the leaf vestiture, which would not allow it to reach the leaf surface. Furthermore, there can be seasonal barriers, as also illustrated by *Antholcus varinervis*, the adults of which emerge and oviposit in mid-winter when there are no valuable Rosaceae in leaf but strawberry.

(3) It sometimes happens that though there may be no related crops of economic value, there are often many closely related ornamental plants; the latter are of very great value in any country, and when it comes to a decision between them and weeds of major agricultural importance consideration must be given as to what is the greater evil—the uncontrolled weeds, or the infestation of ornamental plants by the insects used against the weeds. For example, the insects used against St John's wort will most likely attack garden species of *Hypericum*, and we liberated *Tyria jacobaeae* against ragwort in New Zealand even though it attacked cineraria. In both these cases, however, the insects are leaf-feeders and could be readily controlled on garden plants by means of insecticides If stem-borers were involved, their control on garden plants would be a much more difficult matter.

(4) Another feature that should not be overlooked is that, although there may be no plant of economic value likely to be attacked in the country when an insect is established against a weed, the time may come when it is to the advantage of the country to import and develop such a plant.

(5) When the biological control of weeds and of insect pests is being undertaken in one country, it can happen that the imported entomophagous insects attack the imported phytophagous ones; this position actually arose in New Zealand when consideration was being given to the importation of a certain entomophagous insect the hosts of which included species closely related to one of the species being used in weed control. On the other hand, indigenous parasites do attack and curtail the influence of imported phytophagous species, as has happened for example in Australia and New Zealand.

(6) Every insect imported for weed control must first be studied in the field and by starvation and preference tests in the laboratory in relation to economic crops similar to those in the country whence it is intended to send the insect, and these tests must be repeated, not only on the same plants but also on likely indigenous ones, in the new country, and under strict quarantine, before liberation can be considered.

An illustration of the necessity to duplicate the tests in the country into which an insect is imported is afforded by our experience with *Coroebus rubi* which was brought to New Zealand for use against blackberry (*Rubus fruticosus*); duplication of the research under quarantine bore out the European observations that the

larvae destroyed the blackberry canes by tunnelling in them and did not attack any other plant except certain roses; but further tests with the beetles revealed that apple foliage was readily acceptable to them.

Such work under quarantine very often presents considerable difficulties, since special insectanes and cages are required and have to be covered with gauze, often of such a mesh as to exclude a large percentage of light and to reduce the temperature perceptibly. Though some insects and plants respond readily enough to such conditions, others do not. For example, in *Apion ulicis* the gonads remained undeveloped until a special quarantine cage, admitting the maximum sunlight and ventilation was designed and put into operation; also with *Coroebus rubi* not only did the host plant fail to thrive, but also the beetle could not be prevailed upon to oviposit until subjected to artificial light.

(7) It is hardly necessary to mention that every care must be taken to eliminate parasites of phytophagous insects used in weed control.

The foregoing is merely a general picture of the situation. There is no doubt that the insect control of noxious weeds can be a powerful asset, as has been proved by experience. If I have tended to stress the possible dangers arising therefrom, it is because we must consider these things.

The CHAIRMAN said that this had been an extremely interesting group of papers. The progress was encouraging but there was a need for more workers, more taxonomists, more means of training, and more co-operation, especially with people using insecticides He would add particularly the need for more fundamental study of equilibrium. He had been greatly interested in Dr. Le Pelley's remark that he might have some parasites useful in Australia.

With regard to weed control, he referred to the importance of competition, in which the insect might be a trigger mechanism. In Fiji, *Clidemia hirta* was occupying almost all the cleared areas because it was taking all the light from other plants. It was reported, from observations in the West Indies, that an insect would be useless, as plant competition only was involved in restricting its abundance there. H. W. Simmonds introduced a thrips from Trinidad before this report came in. The thrips swept through Fiji and wiped out the weed except at the edges of forest because, though it caused only inconspicuous damage to it, it slowed down its growth so that other plants dominated it.

Dr W H THORPE said there were two important points to consider in determining the safety of introducing insects to attack plants.

(a) It is important to test phytophagous insects on possible alternative hosts in large numbers to discover individual predilections. Transference from one host to another is usually brought about by severe selection If any individuals show predilections they should be bred from to see if a strain with a new host-plant relationship results.

(b) Transfer of all possible stages of the insect to the new plant should be tested; it is not sufficient to ascertain only whether it will oviposit on it.

Dr. MILLER said that these were the detailed principles of the tests to which he referred Tests were made over a long period of years in the country of origin and in New Zealand to include large numbers of all stages.

Dr V. B. WIGGLESWORTH, referring to Dr. Le Pelley's plea for more teaching of biological control in the United Kingdom, thought that biological control was so broadly based that the most useful contribution of entomological schools was to provide a very broad concept of entomology, including training in taxonomy, physiology, ecology, etc.

Dr. LE PELLEY agreed with the teaching outlined, but with the addition of something more. He had in mind something in the nature of what was now being done in Canada at the Bureau of Biological Control—post-graduate training of people in the actual job such as the 50—75 students mentioned by Mr. Baird in Canada. It would be good if there were 100 or so in England. More workers were needed and would be got if, after general training, they could go where work on biological control was proceeding and thus could get experience with it.

Dr. *Hem Singh* PRUTHI referred to Mr. Baird's suggestion that workers should keep the Bureau of Biological Control in Canada informed of projects in which they were interested, and himself suggested also that the Bureau should keep others informed—he had heard nothing of its work for seven years. He recommended that the subject should be discussed at a business meeting.

The CHAIRMAN said that it would be brought up at a business meeting.

Mr. BAIRD supported Dr. Pruthi's recommendation and said he wanted to correct the impression that 75 students were all working on biological control. The nearest to a school of biological control was at Riverside, California, under Professor H. S. Smith. There was also a course at Ohio University under Professor A. Peterson

Discussion: **Estimation of Insect Populations in the Field**

The CHAIRMAN asked Mr *A H. Strickland* to open the discussion

Mr. STRICKLAND: When I asked Dr. Hall for some advice on how to open this morning's discussion, he replied that I should aim at the general aspects of the subject rather than concentrate on one specialised problem, and added that he hoped it would not be necessary to bring too much mathematics into it! I can assure you here and now that, although all census work must be based on statistical methods, I intend to leave this branch of the subject to those much better qualified to deal with it. In point of fact I intend to devote the next fifteen minutes to a rapid survey of the methods at present in use for collecting insects on a quantitative basis in the field—I wish I could say "in general use", but it is a regrettable fact that many improved methods do not seem to be in general use solely because they have not been widely publicised. At the end of this time I trust that you will agree with me that many insect census techniques in use at present do not give particularly accurate —or even adequate—estimates of the numbers of insects concerned, and it is to be hoped that a certain amount of standardisation, and perhaps even the evolution of more accurate methods, will result from this discussion.

From the start I should like to make four points quite clear.

First, from the agricultural standpoint population estimates may not have to be absolutely accurate so long as the technique in use gives a valid estimate of insect numbers in relation to economic damage. It is, however, often impossible to evolve a reliable rapid survey technique until fundamental work has been done on the relative efficiency of the various possible methods.

Secondly, it is generally of little value, in fact a waste of money, to carry out insect census work without a fairly detailed preliminary study of the biology and habits of the species concerned.

Thirdly, in several cases of which I am aware, *published results on populations* have proved of little value because subsequent, or even earlier, work has shown that, although the sampling method was quite adequate, the insects were not "extracted" from the plant material with sufficient care. For example, thrips and mites on leaves cannot, surprising though it might seem, be accurately counted with the naked eye.

Fourthly, from a perusal of the available literature it is clear that inaccurate methods have remained in use for considerable periods after much improved techniques have been published. To try to prevent this in future, I have compiled a fairly comprehensive list of the literature on the subject, and anyone who so desires is at liberty to take a copy of it for future reference.

I want now to review briefly those census techniques of particular interest to the medical and veterinary entomologist. The first point of criticism I want to make concerns the standard dipping procedure for estimating abundance of mosquito larvae. This method, of course, does not give a result based on the area sampled, and two Americans have recently produced a rather improved, though (as they themselves say) time-consuming, method whereby an actual estimate of population referable to area and volume can be obtained. This seems a definite advance. Hocking's bamboo pot technique is also of interest, particularly for work on domestic mosquitos. Siphoning water from tree holes seems quite adequate.

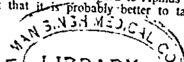
With regard to adult mosquitos, there seem to be a number of good trap techniques available, though the possibility of phototactic fatigue must be considered in relation to light traps of the New Jersey type, and personal factors are likely to enter into investigations based on the rate of landing on individual people.

With regard to "other blood-sucking Diptera", Jackson's marking technique for tsetse flies seems to have been worked up to a reasonable degree of accuracy—a remarkable degree, in fact, when the apparently low density (3,000 per square mile) of the flies is considered. Visual recording of flies settling on bait animals seems open to criticism, particularly in the light of Lawson's recent article in *Nature*, in which he points out that blinking alone is responsible for defective vision 20 per cent. of the time in people with the average "J" type sight.

There is now, apparently, a standardised bait trap for screwworm and blowfly adults in the southern United States, and more uniform census results are being obtained as a result

In considering census work on pests of agricultural crops, I will start with those that attack field crops above ground.

For relatively sessile, or stem and leaf boring, species on graminaceous crops there is little difficulty in obtaining a good population estimate by using any of the recognised plant count techniques and examining the randomly selected plants in the laboratory. The active species are not quite so easy to estimate. Sweep nets have been widely used to collect active insects from grasses and field and truck crops generally, and Romney has recently carried out a comparative test, using two sweep-net methods and a Hills' cylinder trap, for estimating leafhopper populations in the United States. He has concluded that the Hills' cylinder gives better results than either sweep-net method, and produces evidence to indicate that wind velocity and air temperature are sources of error that partly account for inconsistent sweep-net results. Another method, evolved in America by DeLong nearly 20 years ago, consists of spreading a sheet over the ground and then spraying the plants to be sampled. The active insects drop dead on the sheet and can be collected and counted. With regard to Aphids on field crops, Jacob has recently pointed out that it is probably better to take



three leaves, from the base, middle, and top, of each plant, if necessary taking fewer plants per field, than the standardised 100 leaves per field at a rate of one per plant.

There are one or two extraction techniques that deserve mention: Gaines extracts thrips from young cotton plants by means of a Berlese funnel, and Le Pelley has devised a good method for the accurate extraction of thrips from coffee leaves. Newell, in the States, has likewise evolved a technique for extracting web-spinning mites from apple leaves.

Tree crops present rather different and considerably more complex problems. First, it is not easy to take a truly random sample of tree foliage or branches unless a step-ladder is available; secondly, step-ladder work is unsatisfactory in closed-canopy orchard crops because the operator often has difficulty in deciding to which of two or three trees a given twig or leaf belongs; and thirdly, the clatter associated with the erection of a step-ladder is likely to frighten many actively motile species away to less disturbed surroundings. So far as sessile insects are concerned it seems that a random sample of leaves, twigs, or fruit can be taken satisfactorily from a step-ladder, though I have found that the only reliable method for estimating populations of mealybugs on cacao (at a density of about 40,000 per acre, or 70 per tree) is to fell the trees and examine each part minutely with a hand lens. It is obvious, however, that such a technique could hardly be applied on a large scale to valuable stone-fruit trees—and neither would it be necessary if the insects occurred in terms of millions, rather than thousands, per acre. There appear to be almost insuperable difficulties in obtaining an accurate census of active insects of low density on tree crops, and I am hoping that somebody here today will come forward with some bright ideas on the subject.

Considerable advances have been made in recent years in methods for estimating soil fauna, partly due to the Ministry of Agriculture's wartime wireworm surveys. The difficulties associated with soil-fauna work are threefold. First, the size and frequency of the unit sample must be agreed upon, and this of course will depend on the size and density of the insect species concerned. Secondly, there are the problems associated with extracting the insects from the soil sample; for survey work an extraction technique that is as efficient with wet clay soils as it is with light loams or sands must be used. Thirdly there is the difficulty of counting accurately the microfauna, such as Collembola and larval acarines. In brief, Berlese or Tullgren funnels can be used for extracting microfauna from light soils and from litter, but a "wet" method, such as that of Ladell, or the Salt-Hollick modification, should be used where a diversity of soil types has to be sampled, and where accurate figures of soft skinned microarthropods are not of paramount interest.

Finally, I would point out that the bait and light trap methods referred to in the Medical and Veterinary section are also in use for purely agricultural pests and also (in case anybody present is particularly interested in migration work), that net traps for large insects and adhesive traps for small insects probably give a better indication of true density than light or attractant bait traps that are only efficient over a limited area and which depend on sensual reactions on the part of the insects concerned.

Before the discussion begins, I should just like to indicate the subjects that I personally would like a lot more information on. First, what proportion of an insect population should be included in a sample to obtain a valid estimate of density, seasonal fluctuations, and gross population? Secondly, are there any reliable methods for estimating populations of active insects on tree crops? Lastly, can estimates of economic damage be used as a valid index of fluctuations in pest populations?

The CHAIRMAN said that Mr. Strickland had given a very interesting outline of a complex subject of enormous importance to economic entomologists. Essentially, the ultimate problem was reducing an over-large population to a sufficiently small one. Its solution must begin with a study of the bionomics of the insect concerned, and the adoption of a method of sampling its population adapted to its biology.

Dr. R. H. LE PELLEY outlined a few methods that he had used. To ascertain the size of a local population of *Antestia* on coffee, a tree was covered with cloth and sprayed with a concentrated extract of pyrethrum; the insects dropped to the ground and were counted. For chafer grubs, the method was to dig up and examine a square yard of soil. This was too laborious for most people, but perhaps a grab might be used. Flying insects were caught in a net that was attached to the wing of a car and led into a bottle. It sampled as many miles of air as the car was driven through, but air-flow movements would affect the catch. A second method was the use of a trap with nets on two or three rotating arms.

Dr. A. E. CAMERON described recent work with Ceratopogonids, Simuliids and Tabanids in Scotland. Trap boxes served to ascertain breeding places of Ceratopogonids, but it would be difficult to convert numbers taken into population per acre because of extreme variability between boxes only 2—3 feet apart. It was impossible to estimate adult populations.

Simuliid larvae were easily found in communities attached to vegetation or stones in streams, but variability was again a problem. Spates caused shifting of the population, washing the larvae from the primary sites (those attractive to adults for oviposition) to secondary sites at a distance.

It was impossible to estimate populations of Tabanids from the numbers of adults round hosts. Their activity was confined to a short season and depended on weather. Fairly accurate population estimates could be obtained from breeding places in mid-western Canada, where they were restricted, but not in Scotland, where they were more dispersed.

Dr. D. L. GUNN supported Mr Strickland's emphasis on the necessity for knowledge of the behaviour of the animal, and also asked what he meant by "phototactic fatigue" There were always complications when traps were used. Individuals of photopositive animals varied in the degree of their reaction to light in the laboratory, and light-trap samples in the field probably varied every time the trap was used, the difference in catches on moonlight and moonless nights was well known Catches of red locusts obtained by flinging a net over them were much affected by temperature. Early in the morning many fell to the ground and were lost in the grass, but if the temperature was a few degrees higher, most flew away and a smaller proportion was caught. It was therefore important to study a sampling method before it was used

Dr K. B. LAL said that in estimating insect populations in the field, it was important to decide the right stage to study and period of day to do the work, and to ascertain whether the population was homogeneous and allow for irregularities in it In estimating numbers of *Pyrilla perpusilla* on sugar-cane, it was sometimes easiest to count only the eggs for the assessment of future populations. It was important to sample populations of the mango hopper (*Idiocerus* spp.) during the hottest part of the day, when most of the adults congregated on tree trunks, branches and leaves in the shade. Populations of Aphids in a mustard field might vary from centre to edge. It was sometimes desirable first to estimate populations by a comparison of methods, and then choose the most convenient if several agreed Methods compared by him in work on cotton Jassids (*Empoasca devastans*) in the Punjab comprised sweeping; counting nymphs on plants selected at random, placing leaves from different parts of plants in

cellophane bags and counting nymphs and adults on them; and covering whole plants with light metal cones, fumigating them with calcium cyanide and counting the insects that fell on to sheets beneath them. The assessment of populations was important for evaluating the intensity of pest attack, though there were not necessarily reliable relationships between population and damage at any one time. The actual damage caused was sometimes acceptable for determining where control was necessary, as in the case of the number of dead hearts caused by sugar-cane borers, but it might not be suitable for estimating populations. Assessment of insect populations should be based on the habits of the species concerned. For an agricultural entomologist, it was important that methods chosen should be practicable, quick and reliable.

Mr. J. W. McHardy cited observations on the swede midge, which has 2–3 generations a year in Britain, to show that damage cannot always be taken as an indication of population. Attack early in the season reduced the eventual weight of the "bulbs" considerably but late attack did not. Thus loss of weight might indicate either a small early population or a large late one.

Dr. D. W. Williams discussed the difficulties of estimating populations of stored-product pests, especially in imported cargoes. These were multiplicity of species, uneven distribution, presence of flying and non-flying insects, and insects within and between the grains. Populations were largest at the top and bottom of the bulk.

In a cargo of 7,000 tons of maize from South America, numerous samples were taken by sieving and 972 insects found in 70 lb. (mostly *Tribolium castaneum*); on incubating 18 lb. to breed out insects inside the grain, a further 563 insects were obtained. This indicated a population of more than seven hundred million in the 7,000 tons of maize, which was a moderately infested cargo.

Dr. C. G. Johnson said that an estimation of a population of insects in the air by sticky traps or nets would be affected by the amount of air that passed the net or trap; the trap or net would be more efficient at higher wind velocities than at lower ones. This difficulty had been overcome at Rothamsted by the use of a suction trap with a fan that revolved in a horizontal plane and sucked down air at a constant rate at all relevant wind velocities.

The problem of estimating dense populations of insects on plants (*e.g.* the bean aphis) was met by washing the insects from the stems with a solution of detergent and stirring them up in a known quantity of water. A statistically satisfactory number of samples was run off during the stirring process, and this enabled the total number of Aphids in the suspension to be calculated within known limits of error. The method depended on the fact that the numbers obtained in the samples *fall into a Poisson series where the mean is equal to the variance.*

He asked whether the difficulty, raised by Mr. Strickland, of how to decide on the size of a field sample could be approached in this way.

Dr. F. I. van Emden said that in making net catches, weather conditions should be registered, as only *catches made under similar conditions* were comparable. Movements of insects that migrate actively must be considered; thus the onion fly might occur on flowers near an onion field while it was absent in the field itself.

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MEETING: Tuesday, 27th July, 10.30 a.m.

Chairman: Professor J. W. Munro

Discussion: **Developments in the Control of Stored Products Insects**

The CHAIRMAN said this was the first occasion on which stored-product pests had figured on the agenda of an Imperial or Commonwealth Entomological Conference. It was a sign of the times that this branch of entomology, so long neglected, was now being studied. He called on Mr. F. N. Ratcliffe to open the discussion.

Mr. RATCLIFFE: I am going to confine my remarks to wheat, the only commodity about which I am competent to speak. The problems of other grains are probably not essentially dissimilar; and of course wheat is more important than the rest put together.

In dealing with wheat infestation, we are not up against the insects themselves so much as the conditions of handling and storage that blunt the entomologist's weapons and cramp his style. This applies to many aspects of pest control; but to none, I think, more than this one.

Fumigation still remains the only generally practicable means of dealing with an established infestation, but in a country not well equipped with closed-bin silos, the fumigation of big parcels of wheat is no easy matter. In Australia we were driven to erect gas-tight walls around huge bag stacks—a cumbersome process—and to construct a special silo at one of our ports. Bag stack fumigation and treatment in this special silo, were regarded as last-resort measures.

Mineral dusts, which have been intensively studied during recent years, and which can protect grain from infestation, are not suitable for treating bulk wheat because they create bad working conditions. Their application to bagged wheat involves immense labour—breaking stacks, cutting bags, mixing, rebagging, restacking. They have been used, however, to a limited extent, at any rate in Australia, for the surface treatment of heaped bulk wheat, and for farm-stored grain sorghum in Queensland.

The exploitation of DDT and BHC against grain insects is severely limited by the prevalent fear of their toxicity to human beings.

Thus, when you survey the field and spotlight the measures that are actually employed in practice on any scale, you are forced to the conclusion that recent technical advances in the control of stored-wheat pests are not startling. Most of the infested wheat that has been treated has been fumigated with materials that have been known and used for years, for example, Cyanogas.

This of course is a one-sided picture, and takes no account of interesting minor developments and the mass of useful background work that has been carried out. I have drawn it deliberately, to emphasise what I consider the most important development of all, the *organisation* of the attack on the wheat infestation problem. It is primarily because we are up against conditions of handling and storage as much as the pests themselves that the organisation is so important—that the gap between laboratory research and practical application is so wide. You may think that you have a sufficient knowledge of wheat handling, and enough imagination to make sensible recommendations from the lab; but I know from personal experience that when you move from the lab to the conference table, and have to advocate control measures against the background of transport and labour problems, commercial availability of materials, and the like, you move into a different world.



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Dr. J. A. FREEMAN thanked Mr. Ratcliffe for his remarks about the Infestation Division. He said that practical work was impossible without a sound basis of research, which was provided in the United Kingdom by the Pest Infestation Laboratory and the Imperial College. Much of the work done during the war would have been impossible without them.

He showed two lantern slides, of which the first compared the relative intensity of infestation of cargoes from different parts of the world. Commodities from Canada, the United States, Australia and New Zealand were relatively free from infestation; those from South America, Africa, and India were relatively heavily infested. This was probably largely because they were hot countries. However, it was to be noted that cargoes even from the sub-tropical parts of the United States were in good condition. This was attributable to the existence of a good organisation. The West African colonies just shipped them as they were.

The second slide showed shipping routes, which affect infestation. A ship that took Australian wheat to India and then Indian groundnuts to the United Kingdom was found on arrival to have an infestation of grain insects as well as groundnut insects. In another case, grain residue was found to have been left in a ship for at least two years.

The United Kingdom had its own pests and also a vast range coming in. It was impossible to treat everything; the only course was to discriminate between stocks for store and for processing. The responsibility should be moved to the exporting countries. During the war, Canada arranged that all loads should be inspected in the ports before leaving, and treated empty ships if necessary. By this means, infestation was kept very low. A cargo of Australian flour recently arrived in Italy and had to be condemned, but this was rare and the ship had been delayed. The control of stored-product pests was a relatively new and developing subject, and it was difficult to get trained people. An intimate knowledge of practical factors was necessary, and the general agricultural entomologist was not adequately equipped with it. Finally, stored-product entomologists should also be trained in rodent control.

Dr. R. C. FISHER discussed two timber-pest problems of importance in Britain, of which the first was that of the *Lyctus* powder-post beetles. The Chairman had been instrumental in starting investigations on this 25 years ago, but only now was there a prospect of persuading industry to take steps. Before the war, the question of imported material and prevention of spread had been important. Severely attacked timber arrived from America, Japan and even Europe, and it was a question of sterilisation. With the war, we had had to use our own timber, and there was little appreciation of how these insects could build up in timber stocks. The Forest Products Research Laboratory pointed out that great trouble would arise in the war years. It had since come to pass, but industry was now awake to it. With the coming of new insecticides providing an easy means of treatment, it seemed possible to induce people to take action; research had shown that spraying early in spring would prevent infestation. The trouble was particularly severe in utility furniture, and at High Wycombe, the centre of the furniture industry, spraying of stacked timber had been adopted, but there was still the problem of suppliers and imports.

Valuable work had been done in Australia on this subject, but the boric-acid treatment developed there was not applicable to Britain.

The second problem had arisen from the prime importance of building materials and the shortage of good timbers. It had been necessary to use secondary species exploited in tropical forests, many of which were highly susceptible to insect attack. Serious degrade resulted from infestation by pin-hole beetles in green logs. Plywood was being used on an increased scale, and the defects caused by these

insects were important. Control must take place in the country of origin, but thei were no entomologists to do the work. In the Gold Coast, all the onus was c interested forest officers. Forestry schools could do much to meet the lack (entomologists by putting these problems before their students.

Urgent interest had been expressed by the Gold Coast, Malaya and Britis Honduras in preventing infestations, so formulations of DDT and BHC had bee sent out and research was in progress. The results were promising in the Go! Coast but less so in Malaya, and the variation further showed the need fc personnel trained for experiments.

Mr. G. V. B. HERFORD referred to Mr. Ratcliffe's warning of the gap betwee laboratory research and its practical application. Unless research workers we: kept in first-hand touch with problems in the field, much of the value of the work was lost. The Infestation Division of the Ministry of Food supplied a lir in the United Kingdom, but there was no such thing for the Commonweal: entomologists facing these problems abroad, except at conferences. Enquirı were being received from all over the world asking for help. He stressed the need fı details of local conditions when enquiries were made; research workers were anxioı to help, but could not do so without these The research work carried out betwee the two world wars by the Imperial College, due to the foresight of our Chairma was of inestimable value, as it was not necessary to start from scratch when tl second war began. In the case of cereals, however, the start was almost fro scratch, because the cereal people would not co-operate between the wars. Durir the war, hardly any fundamental research was possible at the Pest Infestatic Laboratory, but attempts were now being made to start it again and balance tl research programme by more fundamental work. There were two outstandir problems, the growth of populations and the interaction between insects and fung which he thought were closely linked. With regard to the use of bags impregnate with DDT, it had been shown that 5 per cent. by weight was very effective : preventing infestation of clean contents from outside, and 1 per cent. was qui good. However, there was the question of the amount of DDT picked up fro: the bags, particularly with commodities with a high proportion of fat. Grain ar cocoa beans were the only materials that had a DDT content well below tl tolerance after 13 months. The content was high in flour, and very high in grounı nuts and soya flour

Yesterday we had discussed methods of assessing insect populations had been found possible to obtain overall estimates of the numbers of insec in grain by studying the CO_2 put out by the insects when stored at standaı temperature for a certain period (27° C, 24 hours) The method had been use successfully under Dr. Freeman in estimating the success of fumigation. Tl water content of the grain should be normal.

Dr. W. F. JEPSON supported Mr. Ratcliffe's remarks on the problem presente by peasant-produced grain from experience in Tanganyika, and considered th: the potentialities of DDT and BHC were immense Work on storage problem in East Africa had been carried out by W V Harris during the war. Normal lossı in peasant-grown maize required for food and famine reserve, and kept at goverı ment stores, were estimated. These were the danger spots. The control of Calandı oryzae was the only serious problem, and the difficulty was to ensure the practic: application of measures already well known. Such losses as might have occurre in peace time were taken up by the trade; when the government took over, the amounted to 10—20 per cent. Until recently, no special measures had been take to ensure reasonable freedom from infestation, and many thousands of tons (maize had had to be exported as low-grade stock for animal feed, because (infestation. The first step was the enforced cleaning of godowns, and th measures taken included the use of BHC smoke candles in reasonably gastigh

godowns, spraying as high as a man can reach with DDT, inspection at intake godowns, and dusting of bags with BHC powder in diatomaceous earth before stacking. These measures had been applied in Tanganyika over one whole crop, and the results had surpassed expectation. The spreading power of diatomaceous earth was 3—4 times that of other diluents for BHC. It would be preferable to cut down the use of insecticides by ensuring that the grain reaching the godown was dry and free from infestation. A complete plan for the protection of grain would include the installation of grain dryers to reduce the water content from 15 to 10 per cent., heat treatment, and storage in insulated draught-proof (not airtight) godowns, which prevented any important rise in moisture content, even during the wet season, if the godown was not opened. The use of ·5 per cent. BHC dust would be continued, as it was a single measure that was first class. So far it had killed no one and had had no effect on the health of workers.

Dr. D. MILLFR pointed out the need for suitable workers to carry out research in a monastic atmosphere, where they were not required to produce immediate results and where the problem and not man would be allowed to set the pace. Workers in New Zealand had been faced with a problem of controlling mites in cheese during the war, and had had to attack it blindly with fumigants. They did not know with what mite they were dealing When they studied the systematics, they found that they had a complex of species following a sequence, each with its own reaction not only to physical conditions but also to the fumigants.

Mr. H. T PAGDEN said that in experiments with DDT-treated sacks in Malaya, in which sacks of infested and uninfested grain were kept alongside one another for six months, insects did not spread from infested to uninfested grain if the sack containing either had been treated. He also described treatment of one bay in a large godown of which the rest contained material of various kinds in very bad condition The bay was cleaned out and the floor, sacking and each layer of the sacked paddy that was stored in it was dusted with 5 per cent. DDT in talc. The result was an almost complete absence of *Calandra*. Badly stacked leaking army bags of flour in another part had plenty of *Tribolium*, but rice polishings, which are generally highly infested, in the same bay as the paddy were practically free from *Tribolium*. The mill manager asked for supplies to treat all godowns under his care, and losses that year were infinitesimal. The grain was in the husk so the DDT hazard was small. A heavy deposit (130 and 350 cc. per sq. m) of 5 per cent. DDT on sacks of rice without the husk gave a concentration of 10 parts per million in the grain. As 35 cc. per sq. m. gives complete coverage, the health hazard would appear to be low.

Dr. D. W. WILLIAMS said that in Britain the cereal industry had become increasingly interested in pest control during the last five years. Requests received from firms for services were so frequent and persistent that there was a great danger that some of them would not be met. He hoped that the use of DDT and BHC would not be too much restricted by the possible risk to health. There was a need for more entomologists, more information on insecticides and fungicides, and more work on the health hazard.

Mr. D. J. ATKINSON said that the co-operation of entomologists was seldom asked for by the timber trade because there was no pressure from the consuming end At the Fifth Empire Forestry Conference last year, one of the most important resolutions emphasised the importance of the most economical utilisation of forest products, and another the need for exploitation of secondary timbers. He believed that we were entering an age in which the uses of wood and its processed forms would be greatly increased. The recently developed systemic insecticides that are absorbed by sap and render it toxic to sucking insects might also have an application against Scolytids and other insects that infest timber in the green log.

Dr. R. H. Le Pelley suggested search for means of removing BHC or DDT from grain.

Dr. E. E. Turtle considered that certain resolutions on the subject discussed were desirable.

The Chairman suggested that he should ask Dr. Gimingham to submit such resolutions* to the Business Committee, for consideration with a view to laying them before the Conference.

Chairman: Mr. C. B. Symes, O.B.E.

Discussion: **Tsetse Research and Control**

The Chairman called on Dr. T. A. M. Nash, O.B.E., to introduce the discussion.

Dr. Nash: In spite of the large amount of work that has already been carried out on the tsetse problem, there is still great need for further research, because the problem is of such vital importance to the African. In huge tracts of Africa the presence of tsetse prevents the keeping of cattle. A primitive form of agriculture, combined with dietary deficiency, is to be expected from people who are denied the benefits of manure, draft oxen, meat and milk. Despite large-scale medical surveys and treatment, sleeping sickness still produces much ill-health and, if vigilance is relaxed, causes death and depopulation. I feel that the best use I can make of the limited time at my disposal is to indicate briefly the main lines which tsetse research has hitherto been following. In the ensuing discussion, I hope that workers from other fields will suggest new lines for future research, based on parallels from their own work.

The study of the tsetse presents great difficulties. There are twenty different species of *Glossina*, seven of which are of sufficient economic importance to warrant research. Each species has its own vegetational and climatic requirements, its own host preferences, and its own characteristic behaviour. But this is not all, for in one and the same species the vegetational and climatic conditions, as well as the flies' behaviour, can vary enormously throughout its range. An entomologist with much experience at one end of the species' range, can find himself quite at sea at the opposite end. Take the case of *G. palpalis* in West Africa where it ranges from the coastal, mangrove swamps, northwards, through the forest belt and far up into the savannah zone. The annual rainfall may vary from 200 inches down to 45 inches. In the wetter areas the fly may be ubiquitous, entering villages and native huts, in the drier areas it is purely a stream-bed tsetse, which can only contact man when the latter comes to the water-hole.

Glossina is not an easy genus to study under natural conditions. The observer rarely sees the fly unless it has come to feed off him, or is looking for a mate; what it does with the rest of its time is unknown. Some species present even greater difficulties because the females rarely come to man. In others, such as *pallidipes* and *austeni*, both sexes find man so unattractive that an experienced entomologist may fail to detect their existence unless he uses bait oxen. In the case of the *fusca* group of tsetse it is often easier to find the pupae than the adults.

* See Resolutions 29 and 30, p. 12

We are handicapped in the control of tsetse by the fact that there is no vulnerable egg or larval stage, both the egg and larva being carried within the mother. We have therefore to concentrate on the adults, or on the buried pupae, which are often widely scattered throughout the soil. Another difficulty is that a tsetse population has great powers of recovery. Even though a reduction of 95—98 per cent. of the original population is achieved, the population will soon recover after the relaxation of the control measure. Nothing but complete extermination is of any lasting value.

Twenty-one years ago when I first landed in Africa, I remember asking the late Mr. Swynnerton, the father of tsetse research, such simple questions as "At what time of year are tsetse most numerous?" He replied "We do not know". Since those days we have made great advances in our basic knowledge.

One of the earliest and most productive of techniques was the establishment of the fly-round. At regular intervals, over some years, a fixed number of catchers traverse a route laid out through different vegetation types. From the data collected, valuable information can be obtained as to seasonal abundance, vegetational preferences, etc. By setting up meteorological stations these results can be correlated with the climate. By catching, marking, and then liberating flies, much can be learnt about fly movement and longevity. A great advance was made by Jackson when he evolved a statistical method, based on the recapture of marked flies, from which an estimate can be made of the actual tsetse population in a given area. Recently Vanderplank has evolved a formula for estimating the population of the riverine species, which have a linear distribution. In Nigeria, Johnson & Lloyd worked out techniques for ascertaining the trypanosome infection rates in tsetse, and obtained information as to their natural hosts by measuring the erythrocytes found in the guts of wild flies. In 1933, Buxton & Lewis demonstrated the value of the laboratory approach, and of studying tsetse physiology. Similar work was then carried out in Tanganyika, and by Jack in Rhodesia.

In early experiments on the application of research to eradication of tsetse, Swynnerton tried to drive out tsetse from large areas by inducing very severe grass fires, after several years of fire exclusion. Later, an attempt was made to upset the ecological environment by excluding fire and so allowing the vegetation to become abnormally thick. Meanwhile attention was attracted by Harris' experiments in Zululand to the possibilities of traps. The trouble with all these methods was that, although fly density was greatly reduced, extermination was never effected.

Work was carried out on biological control using the African Hymenopterous pupal parasite, *Syntomosphyrum glossinae*, which can be reared easily in captivity on blowfly pupae. Lamborn tried a small experiment in Nyasaland, and Lloyd & Johnson tried to introduce this parasite in Northern Nigeria. In Tanganyika, the speaker bred and liberated nearly 14 millions of *S. glossinae* in the breeding grounds of *G. morsitans*, but he only managed to raise the general level of parasitisation from 0·2 to 11 per cent. The failure of the parasite was attributed to its inability to penetrate sandy soils. Lloyd repeated this work against *G. palpalis*, which was breeding in humus on an island in Lake Victoria, but had no success; he attributed the failure to excessive humidity in the humus. A pupal parasite could not eradicate tsetse, unless it was able to burrow through sand and humus to a depth of at least 3 inches and, having reduced the tsetse density to a very low level, was still capable of finding the occasional pupa.

Much work has been done on the subject of clearing, by which is meant the felling of the vegetation. The earliest workers observed that where there were no trees there were no tsetse; and found that by felling all the trees, they could exterminate the fly; this is known as total or ruthless clearing. Bax and others tried to cheapen the method by using plant poisons, such as arsenious oxide, but the poisons were too selective in their action. Later on, with an improved

knowledge of the climatic and vegetational requirements of the different species of tsetse, doubts arose as to the necessity for such utter ruthlessness, and from these doubts has arisen the present technique of partial clearing, which covers the terms discriminative and selective clearing.

In the arid north of Nigeria, I studied for some years the ecoclimates and microclimates in the habitats of *G. morsitans* and *G. tachinoides;* the results suggested that at one season the tsetse were living so near to their hot, dry fatal limits that only a slight modification of the forest might destroy them. An experiment showed that the removal of thicket and all trees less than 8 feet in height could exterminate *G. tachinoides* but did not affect *G. morsitans*. This method, modified to suit the milder climate, was tried out on a large scale at Anchau, where *G. tachinoides* and *G. palpalis* were exterminated from 540 miles of stream.

Stewart in the Gold Coast, whilst safeguarding his veterinary station, had also found that it was unnecessary to fell the larger trees. Then Morris, also in the Gold Coast, devised his selective method by which only certain species of the vegetation are removed, these comprising in general the creepers, thickets and low-branching trees. In both cases eradication was achieved.

Discriminative clearing has been used in Tanganyika against the woodland tsetse, *G. swynnertoni*, which has been greatly reduced in numbers by clearing one vegetation association which occupies only 5—10 per cent. of the area. When followed by settlement, Bax has found this method to be completely successful. A method, similar in principle, has been employed with complete success against *G. morsitans* at Abercorn, in Northern Rhodesia, and *G pallidipes* has been eliminated from a small area in Tanganyika by intensive partial clearing.

In all these clearing methods regrowth from the stumps has to be slashed once a year until such time as the stumps are exhausted; alternatively, the clearing can be stumped at considerable expense, and at the risk of producing erosion.

Two successful methods of fly eradication have been evolved in which the vegetation is not cleared. Jack in Southern Rhodesia showed conclusively that *G. morsitans* could be driven out of large areas by game destruction. Symes in Kenya showed that *G palpalis* could be eradicated by hand-catching from blocks of forest that had been isolated by means of barrier clearings, but I doubt whether this method could be employed in places where tsetse can be readily carried across narrow watersheds, and thus reinfest a river system that has been freed by hand-catching.

More recently, Vanderplank found that in the laboratory certain closely related species of tsetse would intermate at random with resultant sterilisation. From these observations he conceived the idea that, having reduced fly density by a cheap method, it might be possible to exterminate the survivors by introducing males of an alien species. The first uncompleted experiment, in which *morsitans* was introduced into *swynnertoni* country, gave disappointing results, but the method is to be given a further trial.

Working under the Colonial Insecticides Committee, a special team has recently started investigations in East Africa with DDT and BHC. Their preliminary trials have shown that, in certain formulations with oils, both these insecticides are toxic to tsetse when applied to vegetation, but that there is excessive loss due to absorption by the leaves. The work is in its infancy but shows much promise. In Zululand, a practical experiment on the use of DDT against *G pallidipes* has recently been carried out in an area of about 100 square miles. DDT in the form of smoke was distributed by air over the whole of this area on six occasions, and in mountainous areas was supplemented by DDT smoke generators. The flies were not eradicated, but the number that survived was small.

It will have been noticed that many methods have failed to produce complete eradication, with the result that as soon as the control measure is relaxed the fly density starts to increase. Apart from the eradication of *G. morsitans* by game destruction, all the large-scale successful methods employed against various species of tsetse have been those in which the tsetse environment has been permanently altered, either by the ruthless removal of vegetation or by the newer and cheaper methods of partial clearing. When the vegetation is left unaltered, measures such as insecticides and hand-catching will remain a perpetual commitment, unless they can achieve complete eradication of the fly; even then, unless the areas are most effectively isolated by barrier clearings, any flies that are carried or wander in are liable to re-establish infestation.

Advances in other branches of science are opening new fields for tsetse research. For instance, by liberating tsetse that have fed on animals containing radio-active salts and using the Geiger-Müller counter, it may be possible to locate inactive tsetse in the field, and to discover new pupal sites if the radio-activity extends to the offspring The discovery of new plant poisons such as 2,4-D (2,4-dichlorophenoxyacetic acid) may lead to a great reduction in the cost and maintenance of clearings.

Now that you have some idea of the problem confronting us, I hope that you will be good enough to suggest in the discussion, further lines that we can follow up.

The CHAIRMAN called on Dr. K. R. S. Morris to make a contribution.

Dr. MORRIS said that outstanding features affecting the control of tsetse in West Africa were the huge size of the problem, especially that of sleeping sickness, and the fact that the vectors are almost exclusively riverine. The Gold Coast is a small corner of a sleeping-sickness area with high infection rates covering 90,000 square miles of the Gold Coast and French West Africa, and other areas in Nigeria, the Congo and the Cameroons are probably bigger. The agricultural and economic aspects may be even more important than the medical one. The main vectors are *Glossina palpalis* and *G. tachinoides*, which inhabit narrow forest fringing permanent water This water is essential for the human population, so that there is inescapable contact between the fly and the people in the savannah. It is here that the most severe outbreaks of sleeping sickness occur. As the same species of *Glossina* transmit animal trypanosomiasis, the waterways are extremely dangerous for stock also. The contest between man and the fly depopulated the rivers before sleeping sickness killed the whole population. The people went to hilly country and erosion and soil exhaustion resulted, so that the final position was more serious than the initial sleeping sickness. However, in some places man had won and maintained fly-free land for himself. This pointed to the possibility of permanent reclamation.

The size of the problem necessitates control measures that are simple to carry out and cheap in maintenance. Mass treatment of the population had reduced sleeping sickness to a low rate, but could not eradicate the trypanosome. Diagnosis was never complete, a few cases were missed, and the fly was left to carry the disease if any remained or if it was reintroduced. Consequently, the big and costly mass treatment organisations of the French, Belgians and British landed them in a dilemma; low incidence cannot justify expensive methods, yet these cannot be relaxed for fear of renewed outbreaks. Entomologists were called in. In the Gold Coast, work started late (1937) and profited by experience elsewhere. Because of the size of the problem, eradication of the fly was always in mind, and, if possible, stable eradication Selective clearing has effected eradication. It arose through research for indicators of the presence of *G. palpalis* and

G. tachinoides. These were found. Their subsequent removal throughout a whole river made the river-side untenable for the fly, which usually disappeared within a year. In the rainy season, in three months, the fly may spread 10 miles along open river and often spreads 4—5 miles. The first experiment was made over 1,000 square miles and led to a reduction of 98 per cent. in sleeping sickness as compared with 1938, the year before the experiment was begun. The operation is being extended, and eventually the disease is bound to disappear. The fact that tsetse could be removed by the elimination of certain plant species only, suggested the eradication of their habitat over whole districts. Maintenance is trivial; weeding every third year as a precaution takes 2—4 man-days per square mile per year, if the area is divided into three, and a part done each year. The task is easy with a population of 20 per square mile. At lower population densities, serious trypanosomiasis does not occur. In this way, the natives are being enabled to occupy the river banks, farm them and graze them, and they will thus cut a great deal more than is necessary and ensure stabilisation and consolidation of the entomologists' gains

Mr. F. N RATCLIFFE thought the co-operation of plant ecologists might be valuable Might not Dr Morris be starting an unwanted long term change in that the regeneration of high trees might be prevented?

Dr. MORRIS replied that local agricultural officers had studied the changes and were satisfied that the grass cover that replaced closed bush was an improvement Closed bush had a bare forest floor liable to constant erosion, when this was replaced by grass cover, the soil by the river bank was stabilised. The use of the ground in co-operation with the Agricultural Service would ensure an eventual state better than the initial one.

Dr. W F. JEPSON said that permanence depended on an active policy of settlement, and asked how the cost of maintenance could be cut down.

Dr. MORRIS said that as sleeping sickness was not serious with a population below 20 per square mile, it was possible to concentrate the work on sleeping-sickness areas Settlement was being encouraged, and until the strips were populated government labour was used

Dr. JEPSON asked whether there was no risk of the introduction of *Anopheles gambiae* in the cleared areas.

Dr. MORRIS replied there was no evidence of this, but it was a long-term problem that needed study.

Mr. M. C MOSSOP said that Southern Rhodesia had effected the greatest reclamations from tsetse in all Africa. The work was started by Jack and continued by Chorley. The species was *G. morsitans*, which had become almost extinct in 1896 through reduction of game by rinderpest. It recovered, occupied a belt and was returning to the rest of its previous haunts This was in the northern part of the country only, though there was game in the whole country. It became necessary to protect farms from nagana, there was no sleeping sickness to speak of They had to have a prompt and sure method, they chose reduction of game by shooting between fences 10 miles apart The process was gradual; the supply of ammunition was restricted so that all game animals shot were used for food, and some were not shot, but driven away. Elephant, hippo, rhino, giraffe and other species that might have been exterminated were spared whenever possible. Once game was reduced sufficiently, another strip was taken in, and game allowed to increase behind the lines In 25 years, 10,000 square miles had been reclaimed Territory was reclaimed only as required by the government Complete eradication had not yet been attempted. Other species (*G pallidipes* and *G. brevipalpis*) occurred on the eastern border and across it in Portuguese East Africa. These

were thicket-inhabiting species against which game reduction was not adequate. A barrier clearing 40 miles long and a half to two miles wide had been made and was reasonably adequate, but it was very expensive to keep clear and flies crossed it occasionally.

Dr. A. E. CAMERON asked whether the process of selective clearing was a mechanical one. When certain bushes and trees had been associated with tsetse, did the question resolve itself into training native teams to recognise them and eradicate them or might the species under different conditions have different forms of growth?

For Dr. MORRIS it was said that natives were taught to identify the species, but that observation must be maintained.

Dr. MORRIS added that, before embarking on a dangerous experiment, they had the example of prosperous areas that had been occupied before sleeping sickness became serious (almost at the beginning of this century) and in which the people themselves had cleared every swamp and river in order to provide farm land and building poles.

Dr. D. L. GUNN asked whether Dr. Nash could foresee any large-scale use for insecticides against tsetse. He also asked whether it was likely to be possible to set up absolute barriers and prevent re-colonisation.

Professor J. W. MUNRO suggested the need for study of the problem by forest departments in Africa.

The CHAIRMAN said all agreed that entomologists had not made sufficient use of forestry people, but that was not entirely the entomologists' fault. Perhaps forestry people were too busy. Closer co-operation was needed on this tremendous problem, which was largely ecological.

Mr. J. W. MCHARDY asked whether any association between certain species of vegetation and tsetses had been observed in the *morsitans-swynnertoni* areas in savannah.

Dr. J. S. KENNEDY recommended a concerted study of behaviour of *Glossina* and made comparison with Muirhead Thomson's work on mosquitos. He thought more knowledge of behaviour would improve the background of control workers, and suggested concentration on the problem of larviposition sites. Laboratory study needed development. He envisaged work in large cages under semi-field conditions, where vegetation could be modified and very large numbers of flies used.

Mr. P. F. MATTINGLY thought selective destruction of vegetation was less likely to promote breeding of *Anopheles gambiae* than indiscriminate clearing, which would expose ground to sun. In relation to the absorption by vegetation of DDT applied from the air, he mentioned the Alaska project—the extermination of mosquitos breeding in temporary pools formed by melting snow, by spraying from the air before the snow melted. In Northern Nigeria and the northern Gold Coast, vegetation died down in the dry season, and *A. gambiae* was then almost absent. It was not known whether repopulation was by hatching of drought-resistant eggs or immigration. Spraying before the rains began would catch *gambiae* when it was numerically weakest and interference from vegetation was least. Would this apply also to tsetse control?

The CHAIRMAN said they were trying to arrive at a method of spraying vegetation against tsetses. With the formulations available, serious loss of insecticide occurred through absorption by vegetation. This was particularly so with oil solutions.

Professor T. W. KIRKPATRICK stressed the absolute necessity for a sound, planned scheme for the settlement and utilisation of reclaimed land. The tsetse was efficient in preventing erosion. At Shinyanga, land reclaimed by Swynnerton was overstocked and becoming badly eroded.

Mr. E. F. WHITESIDE said that Ford was undertaking the study of tsetses where they now occupied country formerly occupied by man. Tsetse took possession because of some change, probably brought about through the arrival of Europeans, that should perhaps be reversed.

Dr. NASH, commenting on various points raised, said that, with regard to insecticides, the Chairman had referred to the preliminary problem of absorption. To be effective against *Glossina*, an insecticide would have to leave a deposit lasting 50 days to kill adults emerging from pupae. The areas involved were colossal, and the cost of repeated applications prohibitive, but they were trying in Uganda to find a lasting insecticide. The amount of clearing necessary for barriers varied enormously. In Northern Nigeria, one mile of ruthless clearing on a stream would prevent tsetse coming up, but on a river three or four miles were required. The grass met over a stream, but one bank of a river afforded the fly shadow in the morning and the other in the evening. Clearings one mile wide at least were needed for savannah species, and it was necessary to cut down large trees, which provided stepping stones. It was important to get the co-operation of sylviculturists; bush was valuable. Experience in Nigeria indicated that a study of the effect of plantations was needed. Extensive tea plantations were free from *palpalis*. In high forest, *palpalis* frequented rivers, but if the forest was broken up by fire or man, it occurred by the streams. A continuous forest belt was effective protection. These subjects required study by someone with knowledge of forestry. One did get an association of flora with species such as *swynnertoni*. With regard to settlement, in Nigeria tsetse had been eradicated from 600 square miles and new villages had been moved in to make the population larger than the 70 per square mile needed to keep regeneration down. At Anchau, they benefited from agricultural and forestry officers. The whole policy was being planned, farming up to the streams was being enforced, with efforts to increase livestock and reduce grazing on the slopes of the hills.

Though Dr. Morris had said that mass treatment of sleeping-sickness was unsatisfactory, there might be a great future for mass prophylaxis giving six months protection. The question of failure to diagnose in a few cases would not then arise. With regard to *A. gambiae* breeding along cleared streams, it was difficult, as Mr. Mattingly had said, to find it in the dry season. In the Anchau area, there were still borrow pits in the cleared areas and the conditions were so bad that they could not be made much worse.

MEETING: Tuesday, 27th July, 2.30 p.m.

Chairman: Dr. H. H. Storey, C.M.G., F.R.S.

DISCUSSION: The Need for Plant Quarantine on a Continental Basis, with special Reference to Africa

The CHAIRMAN said that plant import control was an old subject at Conferences. The Commonwealth countries had put their house in reasonable order, but agreement on a continental basis, as a first step for Africa, was now suggested. A Conference of representatives of Powers with interests in Africa was to be held early in August, and the present Conference was invited to submit resolutions to it. He invited Mr. G. F. Clay, C.M.G., O.B.E., M.C., Agricultural Adviser to the Secretary of State for the Colonies, who had been at a conference of colonial experts recently held in Brussels, to give the background.

Mr. CLAY: I do not think there is much that I need say with respect to the Conference. You have the resolutions adopted at the Brussels Conference, draft resolutions prepared by the Directors of the Entomological and Mycological Institutes for submission to the two Commonwealth Conferences, and the resolutions recently approved at the Commonwealth Mycological Conference.

I also do not think there is any point in my attempting to argue the case for the conception of co-ordinated action to prevent the importation into the regions stated of pests or diseases inimical to agricultural development. One could only wish that this could have been possible in the days when these backward areas and lands were being developed; then some of the difficulties that have resulted from the lack of international control in the spread and distribution of plant material might not have arisen. But I do wish to draw your attention to one aspect that is not so obvious to delegates. We in the Commonwealth have some of the machinery necessary for co-ordinated action. We have a permanent centre of information, and, in most areas, there is some observation centre in operation through which there is an exchange of information on pests and diseases. Moreover, though continental quarantine is probably a new concept, regional uniformity in regulating the introduction and distribution of plant material is well established in southern Africa by agreement between the Union of South Africa, Southern and Northern Rhodesia, Nyasaland and the Belgian Congo, and similar arrangements for East Africa (Kenya, Uganda, Tanganyika and Zanzibar) were agreed at a conference in 1934 and are working well.

As you all know, there is no permanent centre of information outside the Commonwealth and not very many facilities, such as we have, for action against pests and diseases. The rubber industry in south-eastern Asia is alarmed at the risk of entry of South American leaf disease; Malaya and the Dutch and French rubber-producing countries in that area are all vulnerable and at present dependent for safety on independent action by each one. Furthermore if, as has been suggested, cocoa cultivation is extended to that region, it will be necessary to prevent the uncontrolled importation of bud-wood from countries where disease occurs. It was suggested by the French at the Brussels Conference, and warmly supported by the Belgians, that the two Commonwealth Institutes should be centres of information for the world It is now hoped that joint resolutions from the Entomological and Mycological Conferences can be put before the Conference to be held early in August as an indication of the willingness of the Commonwealth to co-operate.

At the suggestion of the CHAIRMAN, the discussion that ensued largely followed the lines of a business meeting. The Resolutions of the Mycological Conference served as the main text, and detailed consideration of a variety of questions led to the adoption of the resolutions given elsewhere (Nos. 24-28, pp. 11-12). The proposal was that an African Phytosanitary Convention should initially embrace all the territories south of the Sahara, including the Anglo-Egyptian Sudan, Ethiopia and Eritrea; and a suggestion (also implied in the Directors' draft resolutions) that an immediate extension of its scope to include Africa north of the Sahara should be recommended was not adopted, because it was held that, as regards both fauna and trade, northern Africa is better considered to be part of the Mediterranean Basin, the Sahara being a greater barrier than the Mediterranean Sea. Attention was drawn to administrative difficulties in applying the proposed Convention to the Anglo-Egyptian Sudan. The division into regions of the area covered by the Convention was considered of the utmost importance, since it was essential that the regulations applied to the whole area should be as few and simple as possible and should therefore be designed to exclude only those pests and diseases that were a risk to the whole area. This would be possible if the risks specific

to a particular region could be met by regional arrangements. In this connection, the Chairman asked delegates from southern, East and West Africa to outline the present position in these regions.

Mr. M. C. Mossop said that agreement for uniform regulations and certificates in the countries in southern Africa was made at a conference in Salisbury, Southern Rhodesia, in 1931. The countries were to notify each other of the appearance of dangerous pests or diseases within their borders. The Union of South Africa had an organisation for inspection of nursery stock, of which it exported considerable quantities, and the products of reputable nurseries were therefore allowed to enter other countries in the region without special treatment, unless a special pest that it was desired to exclude was known to be present Each country had its own regulations, but there were, in effect, common minima for the region.

Dr. R. H. Le Pelley said that co-operation between the East African territories was close, and legislation in the main uniform. Conferences to settle policy were held periodically. Restrictions between territories were, however, maintained, as some important pests occurred in one and not in others.

Mr. J. T. Davey said that there was no joint policy in West Africa In Nigeria, plant imports were not subject to certification or examination, though there were a few certificates for exports

Meeting: Thursday, 29th July 2 30 p.m

Chairman Mr H G Crawford

History of the Bureau of Biological Control

The Chairman said that, before proceeding to the discussion on locusts and grasshoppers, he would ask Sir Herbert Howard to explain the implications of the separation of the Bureau of Biological Control from the Institute of Entomology, as he thought many delegates did not appreciate the reasons for it. Biological control was of paramount importance to all economic entomologists. it was hoped to maintain liaison so that neither organisation would lose power because the two were separate bodies.

Sir Herbert Howard: The Chairman has told me that the complete separation of the Bureau of Biological Control from the Institute of Entomology has left some delegates uncertain of the existing organisation and finance He has asked me to give you shortly the salient points He added that it would be interesting if delegates could also be told something of the method of financing the whole bureaux organisation

Farnham House Laboratory was started in 1927 from a grant made by the Empire Marketing Board. The Board gave £15,000 for capital expenditure plus a grant for maintenance for a period of five years

In 1929 the New Zealand Government made a special grant so that Farnham House could take over the European end of work on the insect enemies of New Zealand weeds. I mention that here because it appears to be the first example of a special project Farnham House, though always a separate entity, was administratively part of the Institute and its functions were within those of the Institute The Director of the Institute had administrative charge of Farnham House, the Superintendents of which (Dr. Neave for the first year and then

Dr. Thompson) were Assistant Directors of the Institute of Entomology, or Bureau of Entomology as it was then called. The funds of Farnham House were always distinct from those of the Institute. From 1926-27 to 1932-33 Farnham House existed on the original capital grant of £15,000 from the Empire Marketing Board, the £20,000 also granted by the Empire Marketing Board for five years, two subsequent grants of £5,000, each from the E.M.B., and a further grant of £4,000 from the E.M.B. in 1932-33 with a grant of £600 from the Canadian Government for work on projects. The E.M.B. ceased in 1932 and for some time the future of Farnham House Laboratory was in doubt. Eventually, however, as a result of the recommendations of the Entomological Conference of 1935, followed by the recommendations of the British Commonwealth Scientific Conference of 1936, Farnham House Laboratory was continued on an intra-imperial basis with a definite annual grant of £5,025 per year from 1st April, 1937. This sum was to provide the basic expenditure necessary, and any special work asked for by any government was to be charged separately. The governments contributing to this sum were U.K., Canada, Australia, Union of South Africa, India and the Colonial Empire. Canada was much the largest single contributor.

The Laboratory continued at Farnham House, with sub-stations in Europe for the collection of parasites.

When war broke out in Europe in 1939, Farnham House was cut off from its collecting grounds, and eventually in 1940 the whole laboratory was transferred to Canada, where the Canadian Government provided room for it in the Dominion's Parasite Laboratory at Belleville. From there the work was again built up so that at the time of the Review Conference of the Imperial Agricultural Bureaux in 1946 there were, in addition to the headquarters at Belleville, three sub-stations in widely differing climatic conditions—one at Riverside in California, another in Argentina and a third in the West Indies. This year a fourth sub-station was established in Zurich.

After its removal to Belleville in 1940, the Parasite Service, as it was then called, was only nominally part of the Institute of Entomology.

The Review Conference of 1946 considered the whole question of the Parasite Service. It thought that from Belleville its services covered a wider range of climatic and ecological conditions than was ever possible when the work was confined to Europe, although it thought that a European sub-station was still required. It therefore recommended that the headquarters should continue to be at Belleville, at least until the next Review Conference. It also decided that, as it was in fact now an organisation completely separate from the Institute of Entomology, and as its work and staff had expanded considerably and was to be further expanded, it should take its definite place in the Commonwealth Agricultural Bureaux organisation as the Commonwealth Bureau of Biological Control. This proposal was accepted by contributing governments so that from the start of the present Review Conference period, 1st April, 1947, the Bureau of Biological Control has been completely separate from the Institute of Entomology and is now under the direct administration and financial control of the Executive Council in exactly the same way as is each of the other bureaux. The Executive Council has created a Canadian Advisory Committee to act as Council's representative on the spot, continuing a war time arrangement set up when the bureau moved to Canada.

Summing this up therefore it is seen that

(1) The present Bureau of Biological Control began as the Farnham House Laboratory under the administrative charge of the Institute of Entomology.

(2) Its funds were separate from the Institute Funds and were provided by the Empire Marketing Board.

(3) When the Institute came under the Executive Council of the Agricultural Bureaux in 1933, Farnham House Laboratory also came under it, but was still regarded as an adjunct of the Institute of Entomology.

(4) After 1935 its funds were provided by certain countries of the Commonwealth on no set scheme. The fund was kept separate from the Institute fund.

(5) In 1940 it went to Belleville, Canada. Its funds were still a separate fund. It was still nominally an adjunct of the Institute of Entomology.

(6) In 1946 it became an entirely separate bureau under the Executive Council. Its funds, like all the others, were contributed by all countries on the same basic scale of units as all the other activities under the Council.

The Executive Council has five separate activities under its control, namely—

The Institute of Entomology,

The Bureau of Biological Control,

The Mycological Institute,

The ten Agricultural Bureaux, and

The Commonwealth Potato Collection.

Each activity has its separate fund and always has had. The contributions to the bureaux fund were always based on a certain recognised system of units. The contributions to the other four funds were not on any recognised system, but since the 1946 Review Conference each of these funds has been contributed to by all countries on the same unit basis as the bureaux fund.

In calculating the contributions for all of these separate funds, the system is first to estimate the annual expenditure for the coming five years. The expected receipts from printing, interest and sundry items are then deducted from the estimated expenditure. The balance remaining is divided among the contributing countries in the proportion of the number of units for which each is responsible, and this is the sum which is contributed to each of these separate funds each year. It will be noticed that contributions do not cover the full expenditure, but only the expenditure after deductions of the expected receipts. For practical purposes, the only receipts worth consideration are receipts from the sales of publications. This is why the Commonwealth Institutes and Agricultural Bureaux have to restrict the number of free copies granted. These receipts have already been discounted in calculating contributions.

During the present five-year Review period the total annual contributions required came to £127,160, distributed as follows:

	£
The Institute of Entomology	20,740
The Bureau of Biological Control	12,750
The Mycological Institute	12,750
The ten bureaux	72,080
The Commonwealth Potato Collection	8,840

I trust this gives approximately the information that you and the Chairman require.

The CHAIRMAN thanked Sir Herbert for his crisp, brief and complete summary.

The CHAIRMAN called on Dr. B. P. Uvarov, C.M.G., to open the discussion.

DR. UVAROV: The problem of locusts and grasshoppers as agricultural pests has three main features:—

1. Irregular periodicity of the plagues, due to violent population changes. In grasshoppers the changes are quantitative only, but in locusts there are also striking qualitative differences between the swarming and non-swarming phases of the same species.
2. The plagues are seldom local, but usually cover vast territories, overstepping administrative and national boundaries. In the case of locusts, an invasion area may even exceed the limits of a continent.
3. Wide schemes of agricultural development, as a rule, favour the plagues, particularly in the case of grasshoppers.

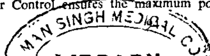
These features affect the relative merits of the three approaches to the solution of the problem, direct defence, outbreak suppression, and prevention of swarming, which are discussed below.

DIRECT DEFENCE

Owing to the relatively simple life-history and open feeding habits of Acridids, their direct control, either by stomach or by contact insecticides, presents a relatively simple technical problem. The recent introduction of such insecticides as benzene hexachloride has made it possible to protect standing crops at a reasonable cost, without any risk to livestock or plants. The consequence has been a tremendous expansion in the use of insecticides and the development of ground and air machinery for their distribution on an ever increasing scale. Antiquated control methods are everywhere being replaced by the use of insecticides. The immediate results are almost invariably excellent, but the interterritorial character of the plagues very often reduces the value of a local success, or even nullifies it, when an area cleared from the pest by insecticides becomes invaded again from outside.

Therefore, an essential condition for effective control by insecticides is the co-ordination of a campaign over the whole infested area. In most countries subject to grasshopper plagues, this condition is difficult to fulfil, as there are no means of ensuring synchronised and equally efficient control by numerous landowners. In the case of locusts, control campaigns have to be planned and executed on an international scale, which it is even more difficult to achieve. In fact, the campaign of 1943—47 against the desert locust (*Schistocerca gregaria*) in the Middle East and East Africa provides the only example of effective international co-operation, and this became possible owing to unique war-time political conditions. The campaign costs averaged over £1 million per year, an expenditure that was justified by the saving of crops but might well be impracticable in normal times.

It is largely because of the impossibility in practice of achieving effective co-ordination of control measures between individuals, territories, or states, that insecticide control of locusts and grasshoppers can never be regarded as anything more than a palliative, and it promises no hope of a solution of the problem. One can go farther, however, and assert that insecticide control is bound to remain a palliative, even with the best co-ordination of effort. An outstanding example is offered by the United States of America, where an efficient Division of Grasshopper Control ensures the maximum possible effort by all concerned.



The result is that each year's standing crops are largely saved; but at an average annual cost of over half a million pounds, and, after many years of organised control, there is no abatement in the grasshopper infestation. The problem remains as acute as ever and expenditure on control must go on indefinitely. The situation in which grasshoppers are regarded as an inevitable evil and their control as a routine annual agricultural practice can, but hardly should, be considered normal. It is a defeatist attitude when entomologists are content permanently "to live with the grasshopper," without aspiring to a radical solution of the problem.

Outbreak Suppression

An outstanding result of the locust investigations of the last 20 years is to be seen in the firm establishment of the principle of outbreak areas, topographically and ecologically limited, where the initial transformation of the solitary phase into the gregarious phase occurs and the first swarms of a plague cycle are formed. The outbreak areas of two out of the three tropical African locusts, the migratory locust (*Locusta migratoria migratorioides*) and the red locust (*Nomadacris septemfasciata*) are already sufficiently defined to permit the organisation of suppressive control. This consists in a permanent supervision of the outbreak areas and the suppression of the small initial concentrations of locusts that might result in swarm formation. The International Red Locust Control Service in Central Africa and the French Migratory Locust Service on the river Niger have both proved, by the discovery of incipient swarms and their timely extermination, that suppressive control is a practical proposition. In order to be efficient, however, organisations for such control must be technically competent and well provided with personnel and transport This makes them too costly for any one state and their international financing is essential, contributions to their upkeep being in the nature of an insurance premium against locust damage.

In the case of grasshoppers, there is also some evidence that plagues originate within certain relatively restricted areas and gradually spread outwards. Some attempts at suppressive control in the outbreak areas of *Camnula pellucida* have been made in British Columbia with considerable success, but the scale of these attempts has been purely local and their value is difficult to estimate

Suppressive control of locusts suffers from the same disadvantage as defensive control—it must go on indefinitely and must never be relaxed. While, therefore, it provides a guarantee against widespread plagues, it cannot achieve a final solution of the problem.

Prevention of Swarming

Such a final solution can only be achieved by making impossible the initial phase transformation in outbreak areas. These areas must possess special ecological conditions that favour gregarisation of solitary locusts, and once these conditions are known, it should not be impossible to alter them in the direction preventing phase transformation. These conditions may be different in the case of each locust, and thorough research in each outbreak area will be necessary before they are fully understood. Locust entomologists, preoccupied with control campaigns, have had neither time nor facilities for such research, but its organisation on a broad and thorough scientific basis can no longer be delayed. Agricultural development of subtropical and tropical countries is proceeding rapidly. More crops of greater value are being produced and exposed to locust attack. Their protection by defensive, or even by suppressive, control is threatening to become too costly in relation to their value, and the prevention of locust swarming should be an essential component of planned development.

With regard to grasshoppers, it must be stressed that agricultural development of new countries almost inevitably favours a number of local grasshopper species, which rapidly acquire the status of major pests This has happened in North and

South America, in Siberia and Australia, and is happening in Africa, where mechanised crop production on a large scale may, at least in some areas, come under a serious threat from native grasshoppers. The study of grasshopper ecology is in its infancy, and in the tropics even their taxonomy is inadequately known. The effects of mechanised cultivation on the local grasshopper fauna must be studied in advance wherever large scale development is contemplated, so as to avoid the techniques favouring grasshoppers.

Conclusions

To sum up: defensive and suppressive control of locusts and grasshoppers have progressed sufficiently to afford a practical measure of crop protection, but they require perennial expenditure on an ever increasing scale. A radical solution of the problem must be sought in prevention of swarming, which requires more fundamental research, particularly in the ecology of populations and of phase transformation. Applied acridology during the two last decades has made great strides in discovering and applying very effective palliatives, and these will serve for a time, but this time must be used for finding a radical solution of the problem by intensive research in permanent prevention of swarming.

The CHAIRMAN thanked Dr. Uvarov and said that with such a provocative opening, they should have a profitable discussion.

Dr. A. J. NICHOLSON then made the following statement:—

I agree heartily with Dr. Uvarov's contention that the aim of locust research should be the prevention of outbreaks rather than the control of outbreaks when they occur. I also agree that this aim is most likely to be achieved by intensive study of the biology and ecology of locusts, and particularly of those factors that cause swarm formation. Practically all of the investigations carried out by our locust team in the Australian Council for Scientific and Industrial Research during the past fifteen years or so have been of this kind, and we still adhere to this principle, although I regret to say that we no longer feel sanguine about the possibility of finding a really satisfactory practical means of preventing outbreaks. The studies already made have been very extensive, and what appears to be a fairly complete knowledge of the biology and ecology of *Chortoicetes terminifera* has been achieved: we know what factors lead to outbreaks, and we know that certain modifications of the environment would go far towards preventing outbreaks. The trouble is that the necessary changes in the environment cannot be made economically, which is largely due to the fact that the outbreak areas occur in regions of comparatively low rainfall. In such regions it is notoriously difficult to make any change in the vegetation. However, the ecological investigations are being continued in the hope that some means of changing the environment may be revealed, or that some new factor may be found that can be used in the prevention of outbreaks, but the studies already made are so extensive that we now doubt if it will ever prove economically practicable to prevent outbreaks by ecological means. That some improvement in the present situation is possible by using such means has, however, been already demonstrated, notably in the reclamation of certain types of bare areas.

In the course of their work, our investigators have become somewhat critical of certain generally accepted ideas about the phase theory, for they do not accord well with observed facts concerning the ecology of *Chortoicetes terminifera*. I have with me a written statement by Dr. Key, which is unfortunately too long to be read in full now, but I will read the portion bearing specifically on the phase theory.

"The distinctness of the habitats (of *C. terminifera*) optimal for the egg stage and the active stages respectively suggests that the most favourable over-all living conditions would be realised in areas where both habitats are present within the range of normal dispersal of the non-swarming locusts, and this is precisely what we find in the soil mosaic of the outbreak areas. Another advantage of the patchy environment from the point of view of survival and multiplication is that it is to a large extent buffered against changes due to weather fluctuations. This characteristic of an outbreak area was emphasised by Kennedy in relation to its effect in "trapping" and holding locusts; he does not appear to have realised its implications in regard to survival and multiplication.

"The generally accepted interpretation of the role of locust outbreak areas is that they provide the conditions under which a *concentration* of non-swarming locusts is brought about, thus setting in train the complex series of changes usually referred to as "phase transformation." They have not been regarded as areas particularly favourable to *multiplication* of locusts, although it has been recognised that multiplication, resulting from a period of favourable weather, must precede concentration. Several leading locust workers have, in fact, put forward the contrary view—that the outbreak areas are regions of precarious existence for the species, situated on the fringes of its range of distribution.

"Workers on *Chortoicetes* have indeed demonstrated the concentrating role of the outbreak area environment, which is most strongly expressed in the outbreak centres. The concentration is brought about as a result of the constant fluctuation in the proportions of the two habitats already mentioned, according to the nature of the season and other factors. However, Key, in particular, maintains that the more important role of the outbreak area is in relation to multiplication, and that *the same patchiness of the environment that causes concentration in* Chortoicetes *and other locusts, is particularly favourable to their multiplication*, owing to the existence of marked differences in the optimal habitats for the different stages of the life-cycle and to the buffering effect already mentioned. On this view, the pre-occupation of most locust workers with the question of behaviour, particularly in relation to phase transformation, and the evident importance of a patchy environment in that connection, has resulted in a failure to appreciate the more fundamental role of the outbreak area, which is in relation to multiplication.

"The Australian locust workers have been very cautious in their attitude to the Phase Theory. Broadly speaking, their view, which is being elaborated by Key in a paper to be published shortly, is that this theory has been extended to cover such a wide range of phenomena that it is extremely difficult to form any clear idea of precisely what propositions are really distinctive of it. In the course of its spread it has taken under its banner, so to speak, fields of enquiry that have little relation to the original ideas that gave birth to it. Moreover, so many of the concepts and terms of the Phase Theory are so lacking in any precise connotation, that it seems preferable, in dealing with phenomena to which a phase interpretation can be applied, to use rather more words to describe precisely what is happening, than to apply the phase terminology.

"It will not be possible for me to go into this subject in detail here, but a single illustration may perhaps help to clarify my meaning In describing what Kennedy has called the "outbreak process," it is customary to designate the crucial phenomenon as "phase transformation," or "transformation into the gregarious phase." The term "phase" implies a complex of physical, biological and behaviour characteristics, any of which may, in fact, be lacking in the particular case under consideration. Some of these, such as gregariousness, are more fundamental in the definition of the concept, while others, such as the physical characters, are chiefly used in diagnosis. But the process with which we are immediately concerned is that of *swarm formation*, and all ambiguity is removed if we substitute that

expression for "phase transformation." From the point of view of locust epidemiology it matters little whether the swarms are composed of individuals with the typical phase *gregaria* structure and coloration, or whether, like one reported by Kennedy, they are indistinguishable from non-swarming locusts.

"Thus, although the Australian workers have necessarily been concerned with many aspects of the biology and epidemiology of *Chortoicetes* that would be characterised as phase phenomena, they have avoided the use of the phase terminology, and believe that they have lost nothing thereby."

Dr. J. S. KENNEDY said that the economic importance of phase phenomena would doubtless be found to vary considerably from species to species among the locusts, but that it was impossible to do what Dr. Key's statement demanded, assess the importance of phase in a particular species, when there were no phase studies available on it—and that was the present position with *Chortoicetes terminifera*.

Chortoicetes, like most of the Old-World locusts, became an important pest only when it launched on mass migrations. In other species, mass migration (or "swarming" to use Key's less precise term) was known to arise out of phase-change. Mass migration was not closely correlated with the morphological features customarily used for phase diagnosis, but it was nevertheless a phase character, and a much more important one, in practice, than morphology. To ignore phase change, which was so indispensable a link in the chain of events leading to important crop damage by these insects, would, sooner or later, cripple efforts to deal with the pest.

In particular, neglect of phase change blurred thought about control strategy. It blurred the distinction between outbreak *suppression* which was already practised on several species, and outbreak *prevention* which, as Dr. Uvarov had just insisted and Dr. Nicholson had agreed, must be the ultimate aim.

Outbreaks—ready-made swarms—could be suppressed without an understanding of phase change in the field, but this was an uncertain, costly and temporary solution at best In order to *prevent* outbreaks it was essential to understand and prevent phase change, for that is what finally engendered mass migration and the act of literally "breaking-out" of the outbreak areas. To do that, it might not be necessary to prevent multiplication. This was the crux of the matter: multiplication and phase change were often successive but obviously different processes, actuated by different aspects of the same habitats. Pessimism regarding the prospects of outbreak prevention seemed hardly justified until every link in the whole chain that makes up the outbreak process had been examined, and this examination was what Dr. Key seemed reluctant to make.

Mr. J. W. COWLAND said that Mr. R. J. V. Joyce, working on grasshoppers of several species in areas in the Sudan in which dura sorghum is under mechanical cultivation, thinks that opening the land in the year before sowing, instead of in the same year, is a possible means of avoiding damage to seedlings.

Dr. Hem Singh PRUTHI agreed with Dr. Uvarov that modification of habitat was the most effective remedy, but he failed to see how the habitat of the desert locust could be changed over the whole vast desert area in India, which was one of the breeding grounds. The stage at which the desert locust could be most easily controlled was the incipient swarm, and he thought what was really necessary was to have an organisation in existence before the swarms formed. A permanent locust organisation was established for India in 1939, and, when swarms appeared in 1941-42 it was ready and only needed expansion. The result was that though the belt of the desert locust extended from India to Africa, there had

been no swarms and no reports of appreciable injury in any part of India during the last three years. The organisation not only informs people how to act and when, but also where. He considered this a practical idea, and thought that every country where locusts breed should have such an organisation.

Mr. J. T. Davey said that there was a permanent organisation in Nigeria, too, but they were very dependent on the vigilance of the local populations. The Government employed ten scouts, but they could not cover 1 per cent. of the small areas that comprise the incipient breeding grounds of the migratory locust. He thought that there was need for more propaganda among the natives, to induce them to scout for themselves, and gave an example of a case in which the local people discovered, reported and dealt with an outbreak, with complete success. He agreed with Dr. Pruthi about the value of an organisation, but thought it most important to advise the native population of the situation and get them to help.

Dr. R. A. E. Galley suggested that control by modification of the breeding areas to prevent swarming might not be so superior to control by suppression of incipient outbreaks in them as Dr. Uvarov thought. Might it not be impossible to carry out habitat alterations over sufficiently large areas, and might not this method be as costly as the use of insecticides? The exact alteration of vegetation required would have to be studied.

Dr. R. H. Le Pelley said that Kenya was very much concerned with preventing outbreaks, as, though there were no known outbreak centres in the country, three species of locusts entered it. The excellent work done in suppressing outbreaks of the migratory and red locusts was appreciated there, and any well-conceived measures against the desert locust would be supported.

Mr. A. R. Waterston said that insecticides might be the answer to the locust problem as Dr Galley suggested, but entomologists could not agree until other methods had been proved to be useless. The dynamics of outbreaks and the new science of outbreak prevention must be investigated.

Mr. P. R. Stephenson said that they had heard from Dr Nicholson that outbreak areas in Australia might be man-made. That might be so in other places. It was important to understand the whole process of phase change, and to keep an eye on changes taking place lest new outbreak areas be made.

The Chairman then called upon Mr. A. B. Baird to discuss the grasshopper problem.

Mr. Baird said that so far locusts, not grasshoppers, had been stressed, but there were only grasshoppers in Canada, where investigations on biological factors in control had been carried out in close association with the United States. For ten years, a detailed study of natural factors regulating grasshopper populations in certain areas had been made, and it had been found that parasites were of greater importance than had been anticipated. Many parasites, including Tachinids, Sarcophagids, Nemestrinids, Scelionids and Bombyliids, were encountered, and the number of species and extent of work on studying them more closely was expanding. Through the Bureau of Biological Control, a similar study was being made in South America, with a view to finding whether the transference of parasites, disease organisms and other control factors could do something to prevent outbreaks. He thought this represented the best possible form of future control.

The Chairman called on Dr Uvarov to comment on the discussion.

Dr. Uvarov said that the main line of divergence between his views and those of Dr. Key, as outlined by Dr Nicholson, concerned phase phenomena, which in practice were an important part of control. Dr Key would concentrate attention on the process of swarming and not on phase transformation, but the speaker could not see how there could be concentration or swarms without early gregariousness.

Though the phases were probably less definite in *Chortoicetes* than in other locusts, he thought it unscientific to disregard phase phenomena, as to do so would be to ignore part of a dynamic process. With regard to Dr. Pruthi's opinion that there was little hope of preventing outbreaks of the desert locust, he pointed out that, though the swarms occur over vast areas, the formation of incipient swarms appeared to be confined to only some parts, mostly coastal, which were beginning to be known. If they were studied and found, he believed they would prove to be less vast than they were thought to be. Suppression methods must be utilised, but they were still only temporary, and a knowledge of causes might provide something more substantial and lasting. With regard to Dr. Galley's suggestion that insecticides might be no more costly than ecological methods, he said that chemicals were known to be expensive; the other method might prove not to be, and it offered more hope. He knew of the work on control by parasites and predators referred to by Dr. Baird and thought it was going well, but considered that a great deal more knowledge of all the factors concerned in the fluctuations of locust populations should be obtained before one, to the exclusion of others, was selected for study. He concluded by saying that he was pleased to have received sharp criticism, as he regarded that as the purpose of the Conference.

Chairman: Mr. F. N. Ratcliffe

Discussion: **Termites**

Prior to this discussion, the delegates had received a summary of information on termites and a memorandum on it, both of which are reproduced below, and also the recommendations of a committee appointed by them, which were substantially the same as Conference Resolutions Nos. 16 and 17 (see p. 10).

Summary of Information on Termites

At the Fourth Imperial Entomological Conference, 1935, the importance of termites in the countries of the British Commonwealth was stressed and, after discussion, a recommendation was made that detailed information should be collected from all countries concerned with a view to deciding what steps, if any, should be taken to reduce the damage done by these pests. To this end, a questionnaire was prepared by the Imperial (now Commonwealth) Institute of Entomology and circulated to all Commonwealth countries. Replies were received from 36 countries* in due course, mostly in 1939, but the outbreak of war prevented any further action being taken.

The information contained in these 36 reports has been condensed in the form of a synopsis, so that delegates to the Fifth Commonwealth Entomological Conference, 1948, can obtain a picture of the problem as a whole and consider whether further action is now necessary.

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* Antigua, Australia, Bahamas, Barbados, Basutoland, Bermuda, British Guiana, British Honduras, Ceylon, Cyprus, Dominica, Fiji, Gambia, Gibraltar, Gilbert and Ellice, Gold Coast, Grenada, Hong Kong, Jamaica, Malaya, Mauritius, Montserrat, Nigeria, Northern Rhodesia, Nyasaland, St. Helena, St. Kitts and Nevis, St. Lucia, Sarawak, Sierra Leone, Solomon Islands, Somaliland, Tanganyika, Trans-Jordan, Trinidad and Zanzibar. The remaining Commonwealth countries had not completed their replies prior to the outbreak of war and were unable to do so subsequently.

While much information was provided under some of the headings of the questionnaire, very little is available under others. Most countries have had occasion to devote some attention to termites as pests of structural timbers in buildings, and in some territories much detailed work has been done on this one aspect of the problem, but almost nothing is known about their attacks on humus or the effects on the soil of their presence in it, while information on their status as pests of growing crops is scanty and vague. Thus, the summary of the problem as a whole provided by the answers to the questionnaire is unbalanced and is to be regarded not only as an account of work done but also as a statement of lack of knowledge and need for research.

The lack of knowledge on many aspects of the activities of termites is not in the least surprising. The problem is so vast that unless at least one entomologist in each territory can concentrate on it alone for several years little progress can be made, and the staff available in most territories, especially in the tropics, has seldom sufficed for this. Moreover, in some countries, if not in all, the study of termites in the field would be a matter not for an entomologist alone but also for a chemist and perhaps a physiologist. The large amount of work done on particular aspects of the problem in certain countries has usually been due to the initiative and interest of individual entomologists rather than to recognition by Governments of the need for the work.

The identity of most of the economically important species is now known for most countries, and the need to separate the species, for practical purposes, into two major groups, the subterranean and the dry-wood termites, is generally recognised. Nevertheless, any extensive research in the Commonwealth generally on their importance in relation to agriculture, forestry and buildings would require the services of a taxonomic specialist if the work were to be on a sound foundation.

It may be considered that the problem differs so much in different parts of the world and is so bound up with local conditions that it would be difficult to devise a general scheme of research that would prove adequate.

The synopsis which follows of the replies to the questionnaire includes only the information contained therein, since this is its sole object. No attempt has been made in it to review work done in foreign countries or work done since 1939 in countries of the British Commonwealth. In order to facilitate reference, the questions that were circulated in the questionnaire are used as headings and are indicated by italics.

1. *A list of all the species of termites known to occur in the country, with an indication of those species that are injurious and their relative importance (minor, medium or major pest)*

The completeness of the list of determined species provided by any one country naturally depends mainly on whether, by chance, an entomologist interested in the collecting and the systematics of termites has happened to live there. Thus, the termite fauna of Australia, British Guiana, Ceylon, the Gold Coast, Malaya, Tanganyika and Trinidad may be said to be pretty well known as regards species present in each, the number of species recorded in these countries varying from 52 in Trinidad to 154 in Australia. In certain small countries, usually islands, such as Jamaica and Mauritius, very few species are present and these are named. Several of the countries that have provided comprehensive lists have classified their species in families and subfamilies.

Indications as to the status, as a pest, of each species have been attempted by several territories, but this is clearly largely guesswork, in the present state of knowledge, except in the case of certain outstandingly harmful species that damage buildings and are well known for that reason

The names of the species known to be harmful are not given in this summary as these necessarily vary from country to country, but complete lists of all the species known in each territory, as well as the names of those that are harmful, are available for reference if required.

2. *Nature of damage to the following, with the names of the termites responsible, where known, or specimens of the insects, and an approximate estimate of the annual damage done*

(a) *Humus in soil.* Extremely little is known about this probably very important subject. In many countries its importance is recognised, but no research has been conducted except in Australia. The general tendency is to assume that termites are harmful because they devour dead vegetation on the surface of the soil, but in a few replies to the questionnaire, notably those from Australia, British Honduras, Sarawak, Somaliland, Tanganyika and Trinidad, there are indications, and in some cases definite statements, that the attack on humus is beneficial, at least in certain circumstances The possibility that the insects are beneficial by breaking down fellings and leaf litter in forests is recognised in British Honduras and Sarawak. In Australia, certain species are definitely considered to be beneficial because much organic material is taken into their underground galleries. An interesting observation in Somaliland is that "ant hills" are numerous where grazing is good, but no opinion is expressed as to whether the converse applies.

The part played by termites in aerating the soil and influencing its chemical composition in areas where the nests of subterranean species are abundant as in parts of Africa and Australia is almost unknown. All that can be said at present is that it is rash to assume that termites are harmful because they devour humus.

(b) *Growing Crops.* Many different opinions are given under this heading. In Nyasaland, Nigeria and Tanganyika, growing plants of various annual crops are damaged, but only sporadically so that the total damage is not serious. A note to the effect that damage to crops is not serious if the soil is well tilled comes from Somaliland. In Malaya there are numerous isolated records of damage to many annual and permanent crops, but this is secondary, following injury or adverse conditions; a similar state of affairs is recorded in the Gold Coast. Seedlings of oil palm, coconut, citrus, etc, in nursery beds are badly attacked in Sierra Leone, mainly after transplanting (which suggests temporary lack of vigour in the plants), and rice and groundnuts are stated to be sometimes seriously damaged in the field there. Clove and coconut estates in Zanzibar suffer 50 per cent. loss of seedlings after transplanting. Sugar-cane is damaged, though negligibly on the whole, in Australia, but in some sugar-growing islands of the West Indies, notably Barbados (and not Trinidad or Jamaica), damage to this crop is certainly not negligible and is sufficient to cause planters to destroy the nests regularly. The only country to record serious damage to a particular crop is Ceylon, where tea is so badly attacked locally, mainly by dry-wood species of termites, that the bushes are eventually killed and at least one estate had to be abandoned while another reported 80 per cent. of the bushes attacked; there is no evidence that damage to tea is secondary. Rubber also is damaged in Ceylon, and also in Sarawak, but in these cases the attack is secondary, following wounds, though attacked trees are otherwise healthy.

In general, it may be concluded that damage to growing crops is not serious, provided the plants are healthy and vigorous, though there are apparently a few exceptions to this

In no instance was it possible to give an estimate of the annual cost of the damage done.

(c) *Forest trees.* Most countries have little or nothing to contribute under this heading, but *Eucalyptus* forests are seriously damaged by several species in Australia. Northern Rhodesia, Nyasaland and Sierra Leone record that damage to growing, indigenous trees is rare and only secondary, but in the first two of these countries, introduced trees, especially *Eucalyptus* spp., are susceptible, and in Nyasaland, Eucalypts are so severely attacked that afforestation is seldom attempted in termite areas, and this is a serious disadvantage. In British Honduras, termites are a major pest of mahogany and pine, the former being damaged to an extent estimated at more than 4 per cent. by value; pine is attacked after damage by fire and these two factors together cause an annual loss in pine of $60,000.

Several countries admit lack of adequate observations on the activities of termites in indigenous trees, so that lack of records does not necessarily mean that no damage is done. Nevertheless, it is fairly certain that indigenous trees, if healthy, suffer little damage in the Commonwealth as a whole.

(d) *Stored timber.* Stored timber is severely damaged in most countries if in contact with the ground, badly stacked, badly ventilated or stored for abnormally long periods. In practice, however, little damage is done because the need for proper storage, not only as an anti-termite measure, but also to guard against rot and for seasoning purposes, is generally recognised, and also because, in most termite-ridden countries, stocks of timber, especially imported timber which is usually susceptible, are quickly used and replaced. In several tropical countries, the only timber stored for any length of time is resistant indigenous timber; thus, in Nyasaland, where there are few stores in any case, the stored timber is mainly *Widdringtonia* which is highly resistant.

(e) *Telegraph poles and fencing.* Wooden poles and fencing posts, except those of resistant timbers, are everywhere destroyed below ground level unless impregnated with a suitable preservative. In most countries, however, the difficulty is overcome, not by impregnation, but by using metal or concrete posts instead of wooden ones, or by using resistant timbers in cases where the cost of metal or concrete posts is prohibitive. Selected resistant indigenous timbers are reported to be fairly satisfactory for this purpose in Australia, Somaliland, Sarawak and the Gold Coast; in the last-named country, wooden posts, if used at all, are of *Borassus* palm, which is very highly resistant

(f) *Government buildings.* Damage to buildings is severe everywhere unless precautions are taken. Both dry-wood and subterranean species are concerned and the indications are that on the whole the latter are the more destructive, but in the West Indies the former, being more widespread, probably do more damage, though subterranean species cause greater and more rapid destruction where they occur. All timber in buildings is liable to be attacked, as the subterranean species as well as the others make their way to roof timbers and do not confine themselves to the foundations and floor timbers Wooden furniture also is attacked almost everywhere in old houses not built to exclude termites.

Most countries are unable to estimate the annual financial loss due to termites in buildings, and none can give a really accurate estimate because no separate records are kept of repairs necessitated by termites alone, nor is this possible in practice. The figures given below as examples are admittedly mainly guesswork:

Malaya.—$350,000 (presumably per annum), or 25 per cent. of the total cost of all repairs.

Jamaica.—80—90 per cent of the total maintenance costs.

Nyasaland.—£400 per annum.

Nigeria.—£4,500 annually in the Lagos area alone.

N. Rhodesia.—A house worth £1,000 costs £30 per annum for repairs to woodwork damaged by termites.

Zanzibar.—£1,000 per annum.

(g) *Private buildings.* No definite information is available, but it is generally concluded that damage to private buildings is greater than that to Government buildings, because private buildings are usually less well protected. It is estimated that 80 or 90 per cent. of all buildings in Ceylon are infested and the British Guiana report includes a remark to the effect that Georgetown is "one large termite mound." If, under "private buildings," one includes the innumerable little "native" houses that are scattered over tropical countries and are constructed solely of materials that are susceptible to termite attack, then the annual loss is enormous and incalculable. Further, the massing of large native populations in towns in wooden buildings built without supervision creates conditions ideal for termites and greatly increases the damage done. This aspect of the problem has received special attention in Jamaica, where need for education, supervision and regulations is strongly stressed by the Government Entomologist.

3. *Methods of Protection*

(a) *Protection of buildings against subterranean termites, with a definite statement as to how far each method adopted is completely efficacious, and a comparison of the lasting value of concrete as against a termite-proof metal course over the whole foundations.*

(b) *Protection of buildings against dry-wood termites.*

These two headings are best considered together, as few countries separate the two classes of termites in describing the methods of protection that they adopt.

The protection of buildings occupies the greater part of all the replies to the questionnaire, this aspect of the termite problem being the only one that has been intensively studied. This was to be expected, since it is as pests of buildings that termites most directly and obviously affect the affairs of man. In all countries, investigations have been directed rather to the construction of buildings in such a way that termites cannot gain access to the woodwork in them than to the control of the insects themselves, which, it is obviously generally felt, is an impossible proposition.

The general tendency everywhere is to substitute concrete for wood in foundations and ground floors and metal for wood in window-frames, doors and other similar structures. There is, however, still no substitute for wood for the supporting structures of roofs, ceilings, and upper floors of certain types of buildings, notably private houses, and for these purposes selected resistant timber subjected to chemical treatment is used wherever possible. The treatment and selection of timbers will be dealt with under Sections 3 (*d*) and (*e*) of this summary.

Two forms of concrete foundations are prevalent. One consists of piles or pillars on which the building is wholly supported and the other consists of a continuous concrete wall or course, all over the ground plan of the building, and concrete ground floors. The former is preferable from the point of view of ease of inspection, but the latter is becoming increasingly favoured for aesthetic reasons. Both are effective provided the foundations are frequently and regularly inspected so that any termite runways can be removed and nests located and treated and any cracks in the concrete filled in, but in practice concrete foundations, though good, are often not completely effective because the human element, in so far as thorough inspection is concerned, is a limiting factor. It can, however, be claimed that both methods are completely effective if proper attention is devoted to the foundations periodically. The most difficult cases to deal with are those in which internal cracks develop in concrete walls so that termites can ascend unseen above the foundations. In such cases, they may not be detected until after they have established themselves in structural timber or in furniture against the walls.

Experience in Australia and Sierra Leone, in particular, indicates that concrete foundations are, in themselves, ineffective, and it appears from experience elsewhere that concrete floors are an essential adjunct if this method is adopted at all. The ideal arrangement, as advocated in Ceylon and the Gold Coast, appears to be a continuous concrete course at least 3 ins. thick all over the foundation walls and projecting 3 ins. both inside and outside the walls; cement floors are joined to this course and since the junction is away from the wall repairs can be effected easily if termites gain access through faults at the junction.

Only a few of the countries concerned have used metal courses in the foundations, and those that have tested them are not satisfied with them as anti-termite measures because it is difficult in practice to ensure permanently satisfactory joints in the metal and around bolts or other items that must pass through it. There seems no doubt that continuous metal courses are inferior to concrete ones, with or without concrete floors. It is pointed out in Jamaica, however, that though a proper concrete course is effective against termites it does not prevent the transfer of moisture from the soil to woodwork when woodwork is in contact with the concrete, and that in structures of this kind the inclusion of a metal course is desirable as a method of preventing decay resulting from damp.

While metal termite-proof courses over continuous foundations are not generally favoured, metal (usually zinc) caps on concrete piles, where the latter are adopted for foundations, are usually, though not invariably, recommended. In Australia, metal caps are placed on the pillars of frame buildings, whether the pillars are of concrete, brick or timber, and this is general practice and is satisfactory if subjected to inspection.

The very detailed report received from Jamaica included full accounts, with diagrams, of anti-termite methods of construction of the foundations of buildings, with special reference to methods of setting wood beams in concrete and joining wooden sills to concrete. The valuable work done in Jamaica cannot be detailed here, but the report should be consulted, together with that from Ceylon, by all concerned with the construction of buildings in the tropics.

The necessity for treating new building sites to free them from subterranean termites and to keep them free as long as possible is emphasised in several countries. The destruction of nests (see Section 5) is an obvious precaution, though often very difficult. In addition, impregnating the soil with sodium arsenite was being tested in Malaya in 1939, and in Nyasaland the foundation trenches of new buildings were impregnated with "Atlas A" solution, but this also was then experimental.

(c) *Protection of stored timber*. Timber is always badly attacked if stored in contact with the ground, but the need for proper storage is generally recognised (see Section 2 (*d*)). The widespread use of concrete floors for timber stores is a valuable protective measure, and this, together with proper stacking on racks to ensure ventilation, usually prevents damage being done in the comparatively short periods during which timber is normally stored in the countries in question. On the whole, the protection of timber in store is obviously not a serious problem, but in Jamaica, where imported timber is stated to be frequently stored in contact with the ground and is often of an inferior quality and highly susceptible, infestation often begins in stores so that timber used for new buildings is sometimes infested at the outset. The urgent need for control by Government of the grade of timber imported and the local timber trade generally is stressed in this instance, and it is also felt that more consideration should be given by the Public Works Department to the termite menace.

(d) *Termite-proofing of timber, giving an account of all the chemicals or processes that have been submitted to a thorough test, with the results obtained, and if possible the names of the termites used.*

All countries have had some experience of the treatment of timber with preservatives, but only a few have conducted adequate experiments and in several of these the experiments had not been long enough in progress in 1939, when the questionnaire was circulated, to yield conclusive results.

The simplest and commonest treatment, and the least satisfactory, is to apply one of several well known preservatives, such as creosote, Solignum or Atlas A, with a brush. Many countries report this as normal practice. One coat is almost useless, but two or three coats give some protection to otherwise susceptible timber in the ground for periods varying up to three years. Brush treatment does not give any appreciable impregnation, and a much more satisfactory treatment, using the same or similar materials, is immersion in hot preservative for 24 hours, followed by cooling in the preservative, or, better still, alternate heating and cooling. A mixture of creosote and diesel oil, impregnated into the wood by this method, is favoured in Trinidad and Jamaica, and wood tar from the local gas producer plant heated with half its volume of crude diesel oil gave complete protection for 15 months, and probably much longer, in Mauritius. This hot-and-cold open-tank method gives penetration in soft woods up to ½ in. Even this treatment, however, cannot be relied upon to give protection to timber in the ground for more than about 10 years in most conditions, though in Malaya the life of railway sleepers thus treated is claimed to be about 14 years. It is generally considered that treatment under pressure is the only satisfactory solution, but this is seldom practised, presumably because of lack of suitable equipment.

Arsenicals (other than proprietary products) do not appear to have been widely tested, but reports from Australia and Northern Rhodesia indicate that they are far more promising than any other materials if impregnated to an appreciable depth. In a "grave-yard" test in N. Rhodesia with a variety of timbers and chemicals, only arsenicals (arsenious oxide and sodium arsenate) were completely successful. Wolman salts (Tanalith) proved the best of several treatments (including creosote, alone and with diesel oil) applied by the open-tank method in tests in Nigeria. Zinc chloride is considered good in Nigeria, but only for use indoors; it is useless in the open because of its solubility.

At the time when replies to the questionnaire were written important "grave-yard" and other tests were in progress in Australia, the Gold Coast, Jamaica, Malaya, Nigeria, Tanganyika and Trinidad. The results of these may now be available and should be obtained

It is important that timber should be well seasoned before impregnation; otherwise cracks will develop and permit the entry of termites despite the treatment. Moreover, the timber should be seasoned in the area in which it is to be used so as to reduce the chance of subsequent cracking through changes in climate. It is also obviously desirable that timber to be used for building purposes should be cut, shaped, bored and otherwise finished to its final form before treatment with preservatives.

(e) *Names of indigenous timbers that have been found to be resistant to attacks of termites.*

Resistant timbers are present in most countries, but none is completely resistant. Resistance varies within one species of timber, and some timbers that are resistant to certain species of termites are susceptible to others. The supply of indigenous timbers is usually limited.

In their replies to the questionnaire, most countries listed timbers known to be more or less resistant, but in most cases these are of only local interest; the lists are available if required. Australia lists 24 species, mostly *Eucalyptus*, that have fairly high resistance to Australian termites. Trinidad claims that five local timbers are highly resistant and are extensively used in consequence, and experiments were in progress there to provide data on the relative susceptibility of all local timbers. Of the several species recognised as resistant in Nyasaland, *Widdringtonia* is outstanding and in general use; so much so that the importance of preservatives and the danger of damage to timber in stores are reduced. Two local trees are used for poles without treatment in Somaliland. The high resistance of the *Borassus* palm in the Gold Coast has already been referred to, but the supply is presumably very limited; its resistance is no doubt well known in other African countries also. Nigeria lists 14 resistant timbers, including the well known *Chlorophora excelsa*, that can be used untreated for sleepers and poles embedded in the ground. Mahogany and teak are fairly resistant. The so-called resistant timbers are only resistant when properly seasoned and free from sapwood. The degree of hardness appears to be the principal factor conferring resistance, but this is a point that requires investigation.

4. *Methods of repairing damage done by termites to buildings, and an indication of their efficacy, in the case of:*

(a) *Subterranean termites.*

(b) *Dry-wood termites.*

The replies received under these two headings are best considered together, as, except in destruction of nests (see Section 5) which is a necessary preliminary to repairs, distinction between the two classes of termites is seldom made in connection with repairs, though actually the destruction wrought by dry-wood species is much more insidious and more difficult to detect and repair than that due to subterranean species.

The methods to be adopted in repairing damage are mainly a matter of applying common sense to each individual case. In general, the repairs consist in replacing damaged woodwork with resistant wood or wood thoroughly treated with preservative, after the destruction of runways and nests. The location of the exact site and extent of the borings of the insects is often facilitated by observing the position of the excrement that falls from them and by tapping the outside of the wood. In some cases it is difficult or undesirable to remove the damaged wood; the best procedure then is to drill holes almost through the infested wood and pour in as much preservative, with the aid of funnel, as the wood will hold, or alternatively blow in Paris green with an ordinary dust gun or fumigate the wood through the hole with fumes of sulphur and white arsenic. Any of these methods is liable to need repeating, and inspection from time to time is necessary. Full details of these and other methods of impregnating, injecting and fumigating wood *in situ* are given in the report received from Jamaica; but it is pointed out there and elsewhere that there is no completely efficacious method that is also economical for dealing with dry-wood termites that are already well established in a building, though the insects can be controlled to the extent that the life of a building is not seriously reduced. In the case of subterranean species it is necessary to locate and block the hole or crack through which the insects entered, after suitable treatment of the soil beneath it; the procedure advocated in Ceylon is to pour down two pints of coal tar creosote at the point of entry and fill with liquid cement. Proper ventilation under wooden floors and in roofs is regarded as an important subsidiary measure in Hong Kong and elsewhere.

5 Destruction of Nests

The destruction of nests is usually difficult and often impossible, and even the locating of them, especially those of non-mound-forming subterranean species, is sometimes impossible.

In many countries it is believed that subterranean nests can be completely destroyed if they are opened up and the queen is located and killed. This is temporarily effective, but is usually not permanently so because subsidiary queens develop and the nest is restored. Much better methods for subterranean nests are fumigation with petrol, carbon bisulphide, arsenic and sulphur, or Cyanogas, or injection of Paris green, white arsenic or calomel. When carbon bisulphide is used, orthodichlorbenzene or chlorinated naphthalene dissolved in it gives a more lasting result, judging from experience in Jamaica. Opinions vary greatly as to the relative efficiency of these various treatments, but all are sometimes completely effective, and the general consensus of opinion seems to be that petrol is the best. Australian experience is, however, that arsenical powders are the only completely satisfactory treatment. Repetition of the treatment is often necessary, regardless of the chemical used. Carbon bisulphide is said to be very effective against mound-forming species in Sierra Leone, but neither this nor Paris green was permanently satisfactory against others. In Barbados, an oil known locally as "sanitary oil" is poured into the nests and is effective, and is preferred to petrol by planters because it is cheaper and safer, though petrol is admitted to be more reliable. The most reliable of all methods, but one of obviously limited application, is the blowing up of nests with gelignite or dynamite. For the general destruction of scattered nests, and the prevention of reinfestation, over a limited area such as a new building site, an arsenical or cyanide dressing over the whole area after breaking up of the soil is recommended. Subterranean nests that are inaccessible can often be dealt with indirectly by injecting Paris green, white arsenic or calomel into the runways in buildings, but repetition of the treatment is often necessary before control is achieved; "back poisoning" results from this method, the insects killed being devoured by others so that the poison is spread through the colony. The same principle is applied to species nesting in wood and others in trees, and the treatment is said to be more effective if a few crushed termites are mixed with the powder and introduced into the nests at the outset. Sodium fluosilicate applied by this method was tested in Australia, but was less satisfactory than arsenicals. A method known as the Thomas Cowan process was used with great success against both wood-dwelling and earth-dwelling species in Mauritius; the composition of the powder used is unknown, but it is believed to include finely divided silica.

In the special case of the termites that nest in and destroy tea bushes in Ceylon, satisfactory control is obtained by injecting Paris green into the infested branches at the low rate of 1 lb. per 3,000 bushes.

It is generally agreed that there is no means of controlling termites completely over a wide area of country. Even the mound-forming species, which are the most easily treated, cannot be eradicated on a large scale except at a prohibitive cost. The methods so far employed are directed only against particular nests or groups of nests that are especially troublesome in or near buildings or on limited areas of land

6. Legislation

Very few countries have any legislation relating to termites. In the Gold Coast, building regulations require that timber posts must be supported on concrete blocks at least 6 ins. clear of the ground, and in Tanganyika, a damp-proof course must be incorporated and this is regarded as an anti-termite measure also. New building regulations that were proposed in Zanzibar in 1939 required either the

inclusion of "ant"-proof courses in all new buildings or an undertaking that structural timber to be used in new buildings shall be either resistant or suitably treated with a preservative. Countries such as Ceylon and Jamaica that suffer particularly severely from the ravages of termites in buildings have no legislation concerning them, and the Government Entomologist in Jamaica stresses the urgent need for such legislation there.

Memorandum on the Summary of Information on Termites

The following notes were prepared by an Australian delegate who has been actively associated with termite research, in consultation with the Officer-in-Charge of the Entomology Section of the D.S.I.R. Forest Products Research Laboratory, which was given the responsibility, by the recent Empire Forestry Conference, of collecting and disseminating information on termites and termite control. It is hoped that they will be useful as a basis of discussion should the Conference decide to set up a Committee to consider the "Summary of Information on Termites" that has been circulated to delegates.

1. *The Need for a Specialist in Termite Taxonomy*

There is, in the British Commonwealth, no specialist in the Isoptera capable of dealing with the group as a whole; and the nature and extent of the attention given by entomologists to termites reflects this lack. Work at all levels suffers when authoritative identifications, and general taxonomic guidance, are not available in a group of insects. The collection and recording of data on the distribution, habits, and ecology of species, and the undertaking of critical experimental work, are discouraged. As a result, entomologists too often remain ill-equipped to give sound and intelligent advice on matters relating to termites, or to maintain the necessary superiority, in knowledge and prestige, over unscientific and self-styled experts in termite control and termite lore.

If the Conference is of opinion that steps should be taken to make good this lack (which can only be done by training up a suitable man), consideration might be given to making provision for the appointee, after a short period of apprenticeship, to work or travel overseas for about twelve months, and perhaps be given similar opportunities at intervals of, say, seven years thereafter.

Unless some such provision is made, it is very doubtful indeed whether the existing gap will ever be filled.

The termites are probably unique among economically important groups in combining taxonomic difficulty with a distribution virtually confined to the tropics and sub-tropics and great biological interest, due to their social organisation and the variety of their nesting and feeding habits Taxonomically the Isoptera are difficult and unrewarding partly because they are, intrinsically, rather unsatisfactory material, and partly because the material available for study is too often defective. (Critical taxonomic work demands full series, which are only obtained by thorough, knowledgeable, and lucky collecting: lucky because winged reproductives—often necessary for the determination and delimitation of species—are only present in the colonies for a short time in the year)

No taxonomist looking forward to a satisfying and interesting life's work could be expected to confine his attention to the Isoptera—to deal adequately with which would be a full-time job—if he were condemned to know them only as spirit specimens. The arrangement suggested should go a long way to insure that the appointee retained his desire to specialise in the group; and by broadening the basis of his knowledge, and giving him the opportunity for personal contact with Colonial Entomologists (whose interest in termites he could be expected to stimulate) it would greatly enhance his value as an authority and referee. The

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location of the taxonomist at a research institute in one of the Colonies would overcome one of the difficulties referred to above; but the almost inevitable tendency to concentrate too heavily on the local termite fauna, and particularly the isolation from other workers dealing with insect groups on a world-wide basis, would probably outweigh this advantage.

2. The Need to Exploit Existing Knowledge in the Prevention of Termite Attack

Although there is a great deal still to be learned about termites the general pattern of behaviour common to the soil-dwelling (" subterranean ") species attacking timber in buildings is well known. So are certain constructional practices or precautions that prevent, or minimise the danger of, this pattern of attack. No one with first-hand experience of termites, and acquainted with the literature, could seriously doubt that " termite-proof " construction is not as efficiently carried out, nor as widely adopted, as it should and could be.

Individual entomologists in certain Colonies have paid attention to this problem, and seem to have achieved fair success, and it has been tackled to some extent in those Dominions in which termites are prevalent. However, it would be as well to recognise that the entomological service and set-up in the Commonwealth as a whole is not really adapted to deal with the problem effectively. Your ordinary entomologist (who is usually an agricultural entomologist), even if he happens to be interested in and adequately knowledgeable about termites, rarely has the time or what might be termed the strategic position to embark on and persist in a campaign for improved constructional practice. It would be unrealistic, in fact, to expect any marked or speedy improvement in the position as a result of advice tendered to works and building authorities by local entomologists

Efficient termite-proof construction depends ultimately on an understanding, by those who design and those who supervise the construction of buildings, of the habits of the insects The understanding can be general and rather elementary, and still be sound and adequate. The necessary information could be provided in a simple manual which combined the essential biological facts with descriptions or specifications of the features involved in termite-proof construction and ancillary precautions. No such publication is known to exist at present.

The prevention of the invasion of buildings by soil-dwelling termites (protection from dry-wood termites, which are generally much less important, demands different techniques) might be defined as 10 per cent. simple entomological knowledge and 90 per cent. common sense, faithful adherence to principles and attention to detail. Until the basic biological facts are made generally available in simple and suitable form, entomologists, called on by circumstances to expound them, will remain liable to become involved in the 90 per cent. of the prescription which should not be their concern.

Discussion

The Chairman said that the termite problem had received much attention at the Fourth Imperial Entomological Conference and, as a result, a questionnaire had been circulated. As the replies were long and specialised, a summary of them and a memorandum on it [both reproduced above] had been prepared for the delegates to the present Conference, and the latter had appointed a committee of those specially interested to study them. Resolutions suggested by the committee had now been circulated. The memorandum, which had been prepared by himself, was the basis of its discussions. It had stressed the need for taxonomic work, and the lack of anyone in the Commonwealth qualified for it. He thought it would be practical to start with African species. Both taxonomy

and biology must be studied; taxonomy was useless without knowledge of biology and agricultural importance. The second resolution had been proposed because it was thought that practical information about the protection of buildings would be valuable. The committee was set up at the beginning of the Conference, when it was not known who would be interested; other people might therefore like to speak about termite work or suggest other recommendations. He knew that Dr. E. McC. Callan would like to and called upon him.

Dr. CALLAN wished to stress another aspect of termite research, and said that universities and other research centres should be interested in it. There were a few places in England at which termite colonies were maintained, but no active work was going on, and there should be a laboratory for it. Termites and locusts were both important, but there had been much work on locusts in the laboratory and little on termites. Löscher of the Swiss Tropical Institute at Basle formerly worked with Dr. Wigglesworth at Cambridge and is now at Professor Grassé's laboratory at the Sorbonne. The work was with the two European species, and the method for culturing them in the laboratory was a modification of the method of Professor Adamson of Trinidad. The incipient colonies were kept between sheets of glass, enclosed completely by paraffin wax for safety and having a glass wool plug. He suggested that research stations in Great Britain should be interested in tropical species, which could be maintained and studied in conditions in which they lived naturally. In view of the importance of termites, it was surprising that there was no laboratory for their study in the Commonwealth.

Professor J. W. MUNRO asked whether Dr. Callan's proposal was in substitution for the proposals of the committee or additional to them.

Dr. CALLAN said it was additional to the first proposal and perhaps less important.

The CHAIRMAN considered it a possible way by which the studies recommended in that proposal could be carried out.

Dr. R. C. FISHER said that a considerable amount of work on the two European species had been done in Berlin during the war and results had been published. They were of vital interest to other European countries. At the Commonwealth Forestry Conference last year, the subject was brought up by an Australian delegate. It was considered that standard tests of preservatives for timber against termites, on the lines of those against fungi, should be carried out. Africa had similar views. He agreed with Dr. Callan that termites could be studied in temperate countries, as locusts had been.

Dr. D. MILLER asked what was the implication of the words "especially in the Colonies," in the first of the committee's proposals. There were termite problems in Australia and New Zealand.

The CHAIRMAN said the wording was deliberate, they had in mind the extremely small amount of work that had been done in the Colonies, whereas there had been quite a fair amount in South Africa and Australia

Professor MUNRO said that the Colonies were stressed because work in them was badly needed and there was reason to hope that funds would be made available if they were referred to specifically

Mr. C. J. GOLLEDGE said that experience in work for Marconi during the war had shown the importance of termite attack on goods in transit by air. In jungle areas, aeroplanes, spare parts and expensive electronic equipment had been damaged overnight. Their protection would be much more difficult than that of buildings or forest trees, and he suggested that the problem should be included in the present resolutions.

Professor MUNRO said that the Colonial Office Agricultur
Committee dealt with stored-product entomology and this included
raised. He doubted whether much headway could be made, unle
and biology were carried on with. He was interested in Dr. Callan's
but knew that some forest workers had thought serious investigation
impracticable in Britain. He would like to hear the views of ot
question.

Dr. FISHER said that a considerable amount of information on di
of termites attacking goods in transit had been collected during the wa
be summarised in the proposed manual. In reply to Professor Mu
that the Forest Products Research Laboratory was very much intereste
termites. Two years ago, they had attempted to introduce them,
had been held up by lack of staff. When staff was available, the wo
continued.

The CHAIRMAN asked whether the delegates desired any recommen
termite damage to goods in transit to be included in the resolutio
opposed this, as the prime object was basic research for fundamental
which should not in the first instance be complicated by *ad hoc* i
He found that the meeting was in favour of leaving the resolutions a
He then said that he must correct one misapprehension of Dr. Call
was one termite research centre in the Commonwealth, in Canada.
know how many termites were there, but a quarter of a million wer
time a test was made, and quite useful experience was gained from
of termites in the laboratory. He was not sure whether keeping col
for study would be profitable.